Measuring and Adjusting Debuncher Tunes

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Last Modified: by Brian Drendel
Created: 5-13-04 by Brian Drendel
Portions adapted from *"Measuring Debuncher Tunes"* by J. Morgan - April 13, 1995
Send comments and suggestions to the **Pbar Tuning Guide Admins**

Production Release 2.13

Introduction:

This document is divided into multiple sections. Click on the section title to go directly to the corresponding section.

1. Introduction: The introduction outlines all of the sections contained in this document and provides quick links that allow the reader to go directly to any section.
2. Revision History: The revision history lists the dates and changes made in each major revision of this document.
3. Prerequisites: This is a list of what items need to be tuned before you can complete this procedure.
4. Background: The background section gives an overview of what a tune is, how to measure a tune and how quadrupoles are used to control the tune. The background section is divided into the following three sub-sections.
    a. What is a tune? This section provides an accelerator physics background on tunes and resonance lines.
    b. Measuring the tune. This section outlines how we can measure the tunes in the Debuncher.

   c. Quadrupoles: This section outlines what quadrupole circuits are used to control the tune in the Debuncher.
5. Setup: This section outlines what setup is required prior to starting this procedure.
6. Full Length Procedure: This is the full length version of the procedure, complete with screen captures and detailed discussion.
7. Condensed Procedure: This is a condensed version of the procedure without any screen captures, nor discussion.
8. Printable Version: The HTML version of this document is optimized for viewing. Go to the printable version for a PDF file optimized for printing.

Revision History:

Before completing this tuning procedure, make sure that you have already verified that the following tuning has been completed:

1. Draft Release v0.10 (4-13-95 by Jim Morgan): Created original procedure.
2. Production Release v1.00 (5-13-04 by Brian Drendel): Re-wrote procedure adding detailed background section.
3. Production Release v2.00 (9-18-04 by Brian Drendel): Passed peer review.
4. Production Release v2.05 (11-15-04 by Brian Drendel): Added to Accelerator Division Document Database Document 1452.
5. Production Release v2.10 (2-8-05 by Brian Drendel): Changed operating point.
6. Production Release v2.11 (3-2-05 by Brian Drendel): Updated Document Database Document 1452.
7. Production Release v2.12 (10-13-05 by Brian Drendel): Modified procedure to match new template. Added Revision History and Printable Documents sections.
8. Production Release v2.13 (10-13-05 by Brian Drendel): Updated Document Database Document 1452.

Prerequisites:

Before completing this tuning procedure, make sure that you have already verified that the following tuning has been completed:

1. Debuncher Bend Bus

Background: What is a tune?

What is the tune and why do we want to adjust it? To answer this question, let's go back and review a some basic accelerator physics. First, we choose a coordinate system in the frame of the Debuncher beam path with x being the horizontal displacement from the center of the beam pipe, y being the vertical displacement from the center of the beam pipe and s being the coordinate in the direction of the beam. The repetitive pattern of quadrupoles around the ring determines the amplitude function, called β (Beta) which has units of length. In turn, the square root of the β function describes the transverse (horizontal and vertical) envelope of the particles motion which varies in the longitudinal direction s. Changing the quadrupoles in the ring will in turn change the β function. Horizontal and vertical components of the β function (lets call them $\beta_x(s)$ and $\beta_y(s)$) can be treated independently by adjusting specific combinations of horizontal and vertical quadrupole strings.

β can also be thought of as an instantaneous wavelength. The tune is defined as the number of transverse oscillations that the beam undergoes in one revolution around the accelerator, and can be obtained from integrating 1/β around the entire ring. So, if we integrate around the entire ring, the horizontal tune is defined as

$$\nu_x \equiv \frac{1}{2\pi}\oint \frac{ds}{\beta_x(s)} \qquad (1.1)$$

and the vertical tune is defined as

$$\nu_y \equiv \frac{1}{2\pi}\oint \frac{ds}{\beta_y(s)} \qquad (1.2)$$

We can see from equations 1.1 and 1.2 that changing $\beta_x(s)$ will change the horizontal tune and changing $\beta_y(s)$ will change the vertical tune. Changing any quadrupole will change the β in both planes. This means that changing a horizontal quadrupole will change both the horizontal and vertical tune, or changing a vertical quadrupole will also change both the horizontal and vertical tune. To change the tune of an accelerator in one plane, both horizontal and vertical quadrupoles must be adjusted together in appropriate amounts.

In circular accelerators, beam traverses the same components many times. For example, in the Debuncher beam will have circulated approximately 1.4 million times during a standard 2.4 second stacking cycle. Magnet technology does not produce absolute pure and uniform magnet fields to steer and focus the beam. We can think of the resulting magnetic field that the beam sees as the sum of the intended magnetic field components and some magnetic field errors. Beam will see these same field errors every time beam circulates, and since beam circulates many times, the transverse displacement due to these errors can add up if we choose the wrong tune.

For example, if we have any dipole field errors then we will not be able to run a integer tune. The reason is that if you have an integer tune, then the beam will return to the same place on every revolution and get the same dipole kick from the field error every time. The displacements will sum over every revolution until the beam leaves the available aperture. This is called an integer resonance. Similarly, if you have quadrupole field errors we will not be able to run a half integer tune. The reason is that if you have a half integer tune, the beam envelope would alternate 180 degrees on every revolution. The result is a quadrupole error will increase the oscillation on every revolution until the beam leaves the available aperture. This is called a half integer resonance. For similar reasons, sextupole errors drive third integer resonances, octupoles drive fourth integer resonances, and so on. In addition, the higher order magnetic elements such as sextupoles and octupoles are nonlinear elements, and can in fact drive many different resonances. For example, a single sextupole can drive an integer resonance, half-integer, 5th-integer, and so on. We want to avoid as many resonances as we can, and as a result we must run at tune values that are not rational.

We have a simple equation that helps us determine what tune values to avoid. ν_x the horizontal tune and ν_y is the vertical tune, and M, N and P are all integers.

$$M \cdot V_x + N \cdot V_y = P \qquad (1.3)$$

If we construct an x-y plot bases on the lines we can draw with equation (1.3) we get what is called a resonance diagram (see figure 1). The lines on the diagram are resonance lines that we want to avoid when choosing values for our tune. It is important to realize that all resonance lines are not equally bad. The order and type of resonance line help determine which lines are more important to avoid.

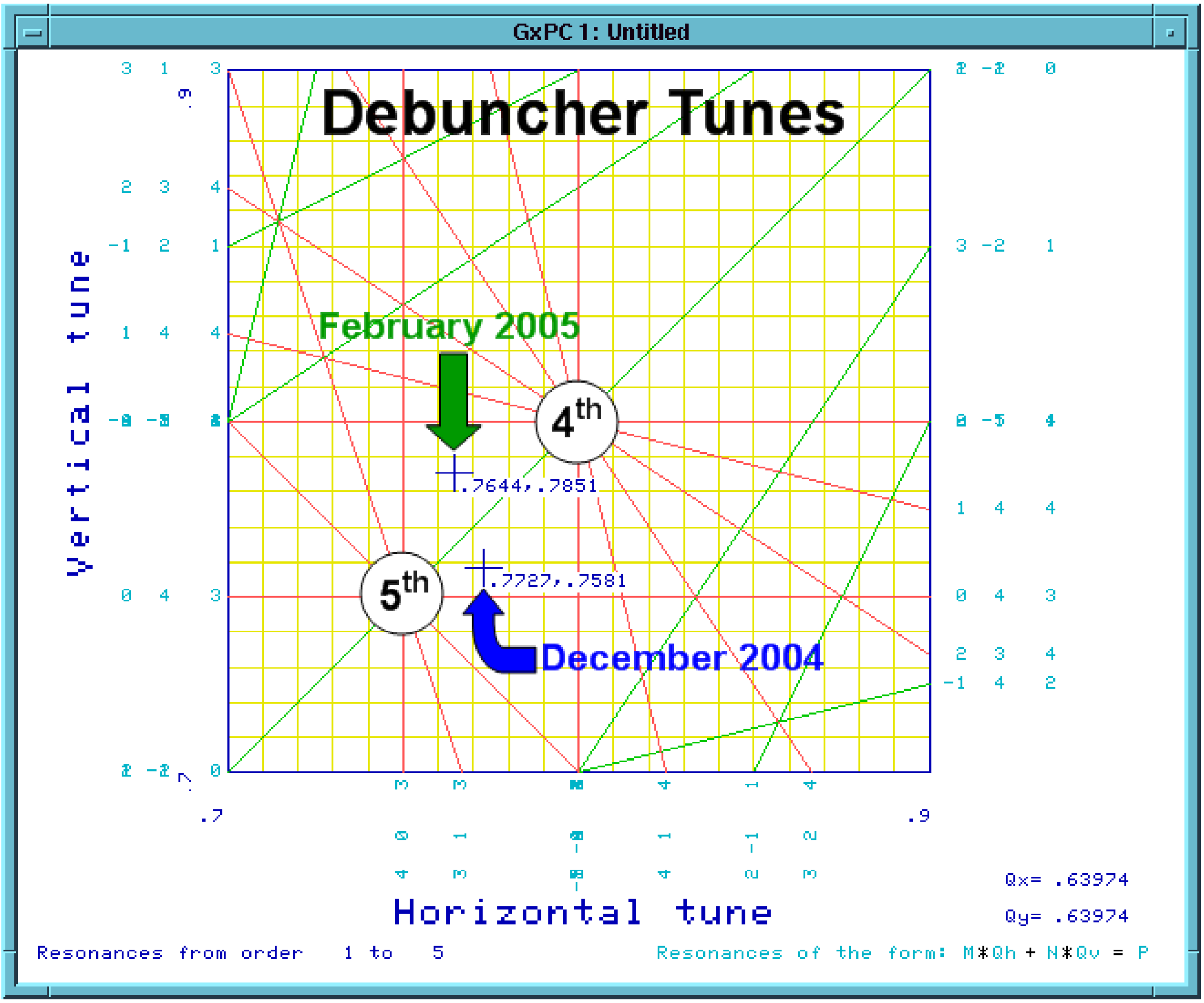


Figure 1a: Resonance diagram generated from Acnet Page P195 showing the default Debuncher tunes. There are multiple working locations for the Debuncher tunes. In the Fall of 2004, we ran at $\nu_x = 9.772$ and $\nu_y = 9.758$. In February 2005 we ran at $\nu_x = 9.764$ and $\nu_y = 9.785$. When this document was originally written in early-2004, the default tunes were $\nu_x = 9.772$ and $\nu_y = 9.758$. Intersection points for 4th and 5th order sum resonance lines are labeled.

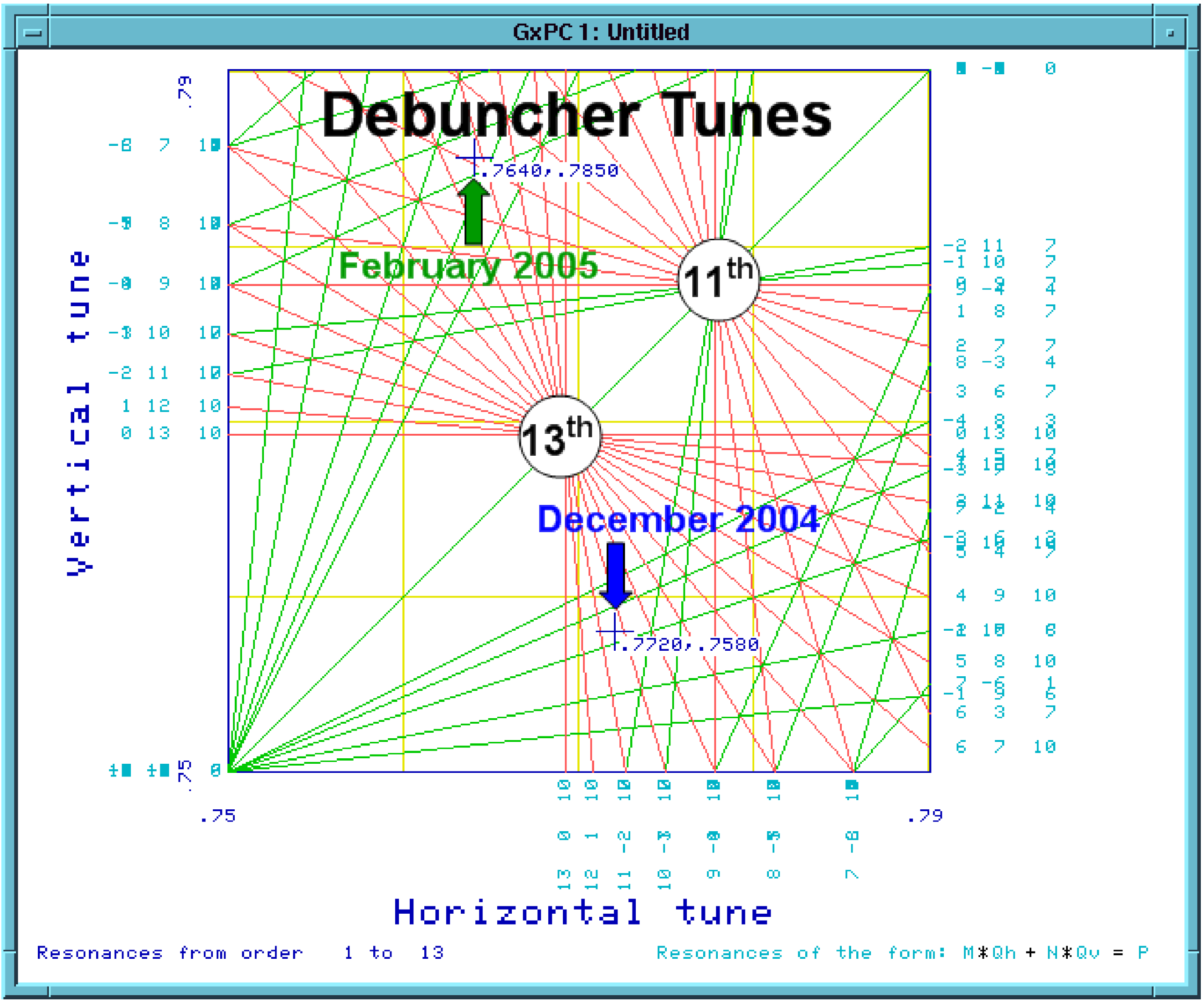


Figure 1b: There are some the believe that higher order effects, perhaps as high as 13th order could have an effect on Debuncher beam. Data from the tune scan shown later in this procedure seems to support this. This figure repeats figure 1a, only on a tighter scale with up to 13th order resonances shown. Intersection points for 11th and 13th order sum resonance lines are labeled.

The order of the resonance is given by

$$|M| + |N| \equiv Order \qquad (1.4)$$

where M and N are the integers from equation (1.3). The lower the order, the more effect they have on beam. The following table shows the first five orders, their corresponding field errors and what resonance lines they correspond to. The further down you go on the table, the less effect there is on the beam. We will assume that orders higher than what is shown in the below table do not have a significant effect on Debuncher beam.

Order	Corresponding Field Error	Resonance
0	Dipole	Integer
1	Quadrupole	1/2 integer
2	Sextupole	1/3 integer
3	Octupole	1/4 integer
4	Decapole	1/5 integer

The order is not the only determination of the effect of the resonance line. There are two categories of resonance lines, called Sum and Difference resonance lines, that have different effects on the beam. Sum resonances occur when M and N in equation (1.3) have the same sign. The lines will be downward sloping (the red lines) on our resonance diagram shown in Figure 1. Sum resonances up to the order 4 are known to create beam loss. Difference resonances occur when M and N in equation (1.3) have difference signs. The lines will be upward sloping (green lines) on our resonance diagram shown in Figure 1. Difference resonances do not have as large of an effect on beam in the Debuncher as Sum resonances.

There are also factors that influence how close the tunes can get to the resonance lines without losing beam. One factor is that each resonance line has a finite width, called the stopband. One way to visualize this is if you trace some of the resonance lines on the resonance diagram in Figure 1 with different width highlighters. The thicker the highlighter, the thicker the stopband. Any beam that has tunes that touch any part of the line would act as if they were exactly on the resonance line. As a result you will be able to place your tunes closer to resonance lines that have thinner stopbands. The stopband is determined by that higher order fields in the accelerator, so the determination and modification of stopband widths is beyond the scope of this write-up. It is important to note that the stopband width is not displayed in the resonance diagram in Figure 1.

Another factor that controls how close you can place the tunes to the resonance lines is your tune spread. The frequency of the betatron oscillations are shifted for off-momentum particles. The resulting change in tune due to momentum is called chromaticity and is defined by the following equation,

$$\delta \nu = \xi(p)\frac{\Delta p}{p_o} \qquad (1.5)$$

where $\delta\nu$ is the tune shift, p_o is the ideal momentum, $\Delta p/p_o$ is the momentum deviation, and $\xi(p)$ is the chromaticity. Since Debuncher beam has some momentum spread, the chromaticity translates to a tune spread. Thus our tune spot on the resonance diagram has a finite size. One way to visualize this is to imagine replacing the cross hairs that mark the tune in Figure 1 with a filled in circle. When any part of the circle hits the resonance line or stop band, the particles with that tune behave as if they were sitting directly on the resonance line. The smaller the tune spread, the smaller the circle is in our resonance diagram and the closer we can place the beam to the resonance line. This is not displayed when you construct a tune diagram from P195.

Chromaticity is controlled by the sextupole magnets. This makes sextupole magnets very important to operation of an accelerator, however, using sextupoles complicates accelerator design. As mentioned earlier, Sextupole magnets also drive resonances. Therefore, it is important that chromaticity sextupoles are carefully arranged so as not to intentionally contribute to the stopband width of resonance lines. Spacing of sextupoles so they do not drive resonances, and determining and tuning the chromaticity to minimize tune spread is beyond the scope of this write up.

The spacing between devices in the Debuncher is another important factor that determines the ideal tune. One example is the pickups and kickers in the Debuncher stochastic cooling systems. The pickups measures a position error in the beam and the kickers provide correction to the measured error. If the path length between the pickups and kickers is an integer number of betatron wavelengths plus 1/4 of a betatron wavelength, then we can make an angular correction with the kickers to cancel out the measured position error. The reason for this is shown in figure 2 below and described in the Pbar Rookie Book v1.1 page 42 "...a particle passing the pick-up at the crest of its oscillation will cross the kicker with zero position error but with an angular deviation with is proportional to the displacement at the pickup." We can thus make an angular correction with the kickers to cancel out the position error that we measured with the pickups.

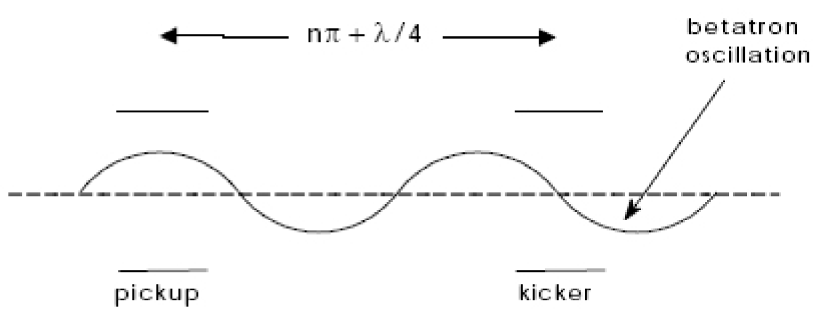


Figure 2: Optimal spacing between the pickup and kicker
(from Figure 5.2 of the Antiproton Source Rookie Book).

If the betatron tune is changed significantly in the Debuncher, then the spacing between pickups and kickers is no longer 1/4 of a betatron wavelength. As a result, the kicker will be applying a corrective signal at the wrong betatron phase, which can reduce the effectiveness of the system. For example, if the tune was changed such that the betatron phase between pickup and kicker was shifted by 180 degrees from the default, then the spacing would be an integer number of betatron wavelengths plus 3/4 of a betatron wavelength. In this case, if the same corrective error was applied to the beam, then the correction would be 180 degrees out of phase and the beam would blow up instead of being cooled. Of course, changes we see in the Debuncher tunes will be far smaller than this; however, they can still effect the betatron spacing between pickup and kicker and make the system less than optimum.

The ideal location of the Debuncher tunes is based on all of the factors that we had covered above. We must choose a spot that does not fall too close to a resonance line, so we used P195 to construct our resonance diagram as shown in Figure 1. We plotted up to 5th order resonances, knowing that any location on the resonance diagram that is not near these lines should be stable. We gave more weight to the Sum Resonances (downward sloping red lines), than the Difference Resonances (upward sloping green lines. We realize that both the resonance line and the tune spread are finite in size, which may further limit what tunes we can run at. Lastly, we realize that other devices in the Debuncher whose efficiency depends on the betatron phase advance, and thus the tune. There are multiple tune locations where the Antiproton Source can run equally well, which can make choosing the operating point difficult. The Antiproton Source department sets the nominal tunes of the Debuncher, but sometimes the default tune values will change slightly over time. For the theory portion of this document, I will use the tune values of $\nu_x = 9.77$ and $\nu_y = 9.765$ as the default tunes. Traditional wisdom tells us that that tunes should be kept within .01 of these nominal values, although there are numerous other locations in tune space that may work just as well. This document will show us how to measure and optimize the tunes.

Background: Measuring the tune.

In order to measure the tunes we connect a spectrum analyzer to Debuncher Schottky detectors in the Pbar tunnel. The Schottky Detectors are most sensitive to beam signals at the 126th harmonic of the revolution frequency. Since we know the revolution frequency of the Debuncher is approximately 590018 Hz, then we know that the 126th harmonic is located at 590018 Hz * 126 = 74.342268 MHz. There are three Debuncher Schottky detectors: longitudinal, vertical and horizontal. The longitudinal detector can be used to determine the revolution frequency of the beam, the horizontal Schottky detector can be used to look at one of the h=126 sidebands to determine the horizontal tune, and the vertical Schottky detector can be sued to look at one of the h=126 sidebands to determine the vertical tune.

When circulating beam is left in the Debuncher over periods of minutes or longer, as can occur during reverse proton studies, P43 can be used to measure the tune in the same way that we normally measure the tunes in the Accumulator. See the Adjusting Accumulator Tunes document for details on that procedure. P43 uses all three Debuncher Schottky detectors to make the tune measurement. It uses the longitudinal Schottky to determine the revolution frequency of the beam, and uses the horizontal and vertical Schottky detectors to measure both upper and lower sidebands to calculate the tunes. A tune measurement using P43 during reverse protons circulating in the Debuncher is shown below. Beam must be present in the Debuncher on the order of minutes to be able to complete this measurement.

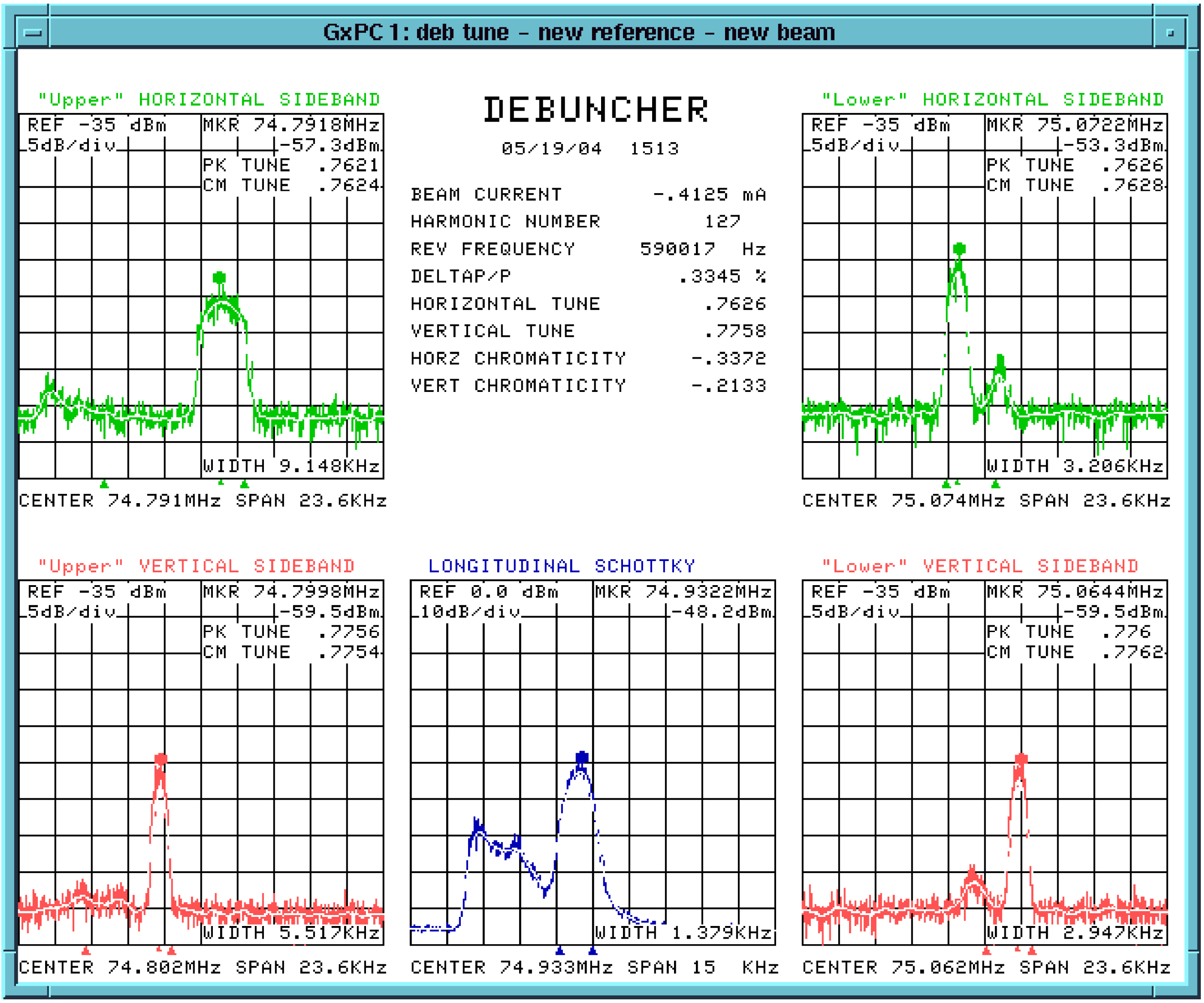


Figure 3: Debuncher tunes measured with P43 with circulating protons.

During stacking operations, it is not practical to use P43 to measure the tunes. When stacking, beam is usually only present in the Debuncher for a few seconds, which is not long enough to complete a P43 measurement. The beam intensity during stacking cycles is also very low. In fact the beam intensity is at least 1,000 times smaller than what is seen in the Accumulator which makes the signal is very noisy. As a result, during stacking cycles, we need an alternative method for measuring the tunes.

This leads us to our tune measuring procedure that we outline below. We will assume that the Debuncher momentum cooling and DRF keeps the revolution frequency of the beam sufficiently close to 590018 Hz, so we will not use the Debuncher longitudinal Schottky. We will use a spectrum analyzer to measure sidebands from horizontal and vertical Schottky detectors, and then calculate the tune based on the sideband measurement.

We have two sidebands to choose from. They are called the upper and lower sidebands. The h=126 lower sideband is used for the measurement of the horizontal tune and is found by the equation

$$f_s = (126 - \nu_x) \cdot f_{rev} \qquad (1.6)$$

where f_s is the sideband frequency, ν_x is the fractional portion of the horizontal tune (i.e. .770 instead of 9.770), and f_{rev} is the revolution frequency of the beam. The revolution frequency of the Debuncher is very close to 590,018 Hz, as mentioned above. Our nominal tune in the horizontal plane is 9.770, so we can plug these values into the equation to get the nominal value for the sideband on the spectrum analyzer (73.8921 MHz). When measuring the horizontal tune this frequency should be used as the center frequency on the spectrum analyzer, and will locate the nominal tune value on the center of the display.

The upper sideband is used for the vertical measurement, and the appropriate sideband frequency can be found by the equation

$$f_s = (126 + \nu_y) \cdot f_{rev} \qquad (1.7)$$

where f_s is the sideband frequency, ν_y is the fractional portion of the vertical tune (i.e. .765 instead of 9.765), and f_{rev} is the revolution frequency of the beam. Plugging in a revolution frequency of 590,018 Hz and a fractional tune of .765 results in a center frequency of 74.80105 MHz. When measuring the vertical tune this frequency should be used as the center frequency on the spectrum analyzer, and will locate the nominal tune value on the center of the display.

Normally either Spectrum Analyzer 4 or 5 is used for this measurement. The Spectrum Analyzer is connected to the correct Schottky Detector, centered on the correct sideband frequency, and setup properly for the tune measurement. We setup the Spectrum Analyzer to trigger at .6 seconds after a $90. This time was chosen because it is after the bunch rotation process has been completed, but before the stochastic cooling system has had a chance to cool the beam which reduces the size of the signal. Complete setup details are covered in the procedure section of this document. After the Schottky signal has averaged over up to 50 sweeps, we view the cumulative trace. The peak of the trace is the sideband frequency, which is not as clearly defined as it is in the Accumulator, but it normally is strong enough to be recognizable. We then measure the sideband frequency peak and use it to calculate the tune.

If we are looking at the horizontal Schottky, the horizontal tune can be calculated from the measured sideband frequency with the following formula.

$$\nu_x = 126 - \frac{f_s}{f_{rev}} \qquad (1.8)$$

where f_s is the sideband frequency measured from the spectrum analyzer, ν_x is the fractional portion of the horizontal tune , and f_{rev} is the revolution frequency of the beam. If we are looking at the vertical Schottky, the vertical tune can be calculated from the measured sideband frequency with the following formula.

$$\nu_y = \frac{f_s}{f_{rev}} - 126 \qquad (1.9)$$

Once the tunes have been measured they should be checked against the nominal values to determine if a tune change is in order. Even if the tunes are not at their nominal values, you can use a tune diagram to determine if the beam is in a stable location away from any high order resonances.

Background: Quadrupoles change the tune.

Once it has been determined that the tunes need to be moved, it is important to understand what devices are changed when moving the tune. It was mentioned earlier that quadrupoles are used to change the tune. The Debuncher has three main quadrupole busses, shunts on many of the individual quadrupoles, motorized stands on some of the quadrupoles, three large quadrupoles that run off of the bend bus, and quad trims on the three large quadrupoles. Only some of these devices, as I will explain shortly, are used to change the tune.

Two of the quadrupole busses, D:QD and D:QF, power all of the quadrupoles outside of the straight sections in the Debuncher. D:QD and D:QF are both 300A orange PEI power supplies located at AP10. D:QF powers all focusing quadrupoles from DnQ7 to DnQ7, where n is the sector number which can from be 1 to 6. Focusing quadrupoles have odd numbers in the Debuncher. For example in sector 10, D:QF would power D1Q7, D1Q9, D1Q11, ...D1Q17, and D1Q19. Due to the mirror symmetry in the number scheme, D:QF powers the same numbered quadrupoles in all sectors. Likewise, D:QD powers all defocusing quadrupoles outside of the straight sections from DnQ6 to DnQ6, where n is again the sector number which can from be 1 to 6. The only exception to this is that D:QD does not power D6Q6 as will be explained shortly. Defocusing quadrupoles have even numbers in the Debuncher. For example in sector 10, D:QD would power D1Q6, D1Q8, D1Q10, ...D1Q16, and D1Q18. Again, due to the mirror symmetry in the number scheme, D:QD powers the same numbered quadrupoles in all sectors. Many of the quadrupoles powered by D:QF and D:QD also have shunts to individually tune the elements. Neither D:QD, D:QF, nor any of the shunts on these circuits are used to adjust the Debuncher tune.

The Debuncher has three large quadrupoles in injection or extraction regions with apertures large enough to house both the circulating beam pipe and the injection or extraction beam pipe. Due to the large current requirements for these quadrupoles, they are powered by the Debuncher bend bus, D:IB. D6Q6 is located at the Debuncher to D-to-A line extraction region, D4Q5 is located at the AP2 to Debuncher injection region, and D2Q5 is located in the decommissioned AP4 line to Debuncher injection region. The AP4 line was a beam line that ran from the Booster to the Debuncher in the pre-Main Injector era. All three of these large quadrupoles has a 100V/600A trim supply, whose Acnet parameter names are D:QT205, D:QT405 and D:QT606. None of the large quads, nor their trims are used to adjust the Debuncher tune.

The Debuncher has one quadrupole bus, D:QSS, that powers all of the quadrupoles in the straight sections. D:QSS is a 300A orange PEI power supply located at AP10. D:QSS powers all focusing and defocusing quads from DnQ5 to DnQ5, where n is the sector number which can from be 1 to 6. For sector 10, D:QSS powers D10Q, D1Q2, D1Q3,D1Q4, and D1Q5. Due to the mirror symmetry in the number scheme, D:QSS powers the same numbered quadrupoles in all sectors. The two exceptions, as explained above, are D4Q5 and D2Q5, which are powered by the Debuncher bend bus and a trim. D:QSS is not used to adjust the Debuncher tune.

The quadrupoles on the D:QSS bus have shunts to individually tune the elements. Below is a list of the shunts.

1. There are three 20A shunts on Q1 magnets in the 10, 30 and 50 sectors. The Acnet parameters to adjust the shunts (and magnet names) are D:Q101RF (D1Q1), D:Q301RF (D3Q1), and D:Q501RF (D5Q1).
2. There are three 50A shunts on pairs on Q2 magnets covering all six sectors. The Acnet parameters to adjust the shunts (and magnet names) are D:Q102RF (D1Q2/D6Q2), D:Q302RF (D3Q2/D2Q2) and D:Q502RF (D5Q2/D4Q2).
3. There are three 30A shunts on pairs on Q2 magnets covering all six sectors. The Acnet parameters to adjust the shunts (and magnet names) are D:Q103RF (D1Q3/D6Q3), D:Q303RF (D3Q3/D2Q3), and D:Q503 (RFD5Q3/D4Q3).
4. There are three 30A shunts on pairs on Q2 magnets covering all six sectors. The Acnet parameters to adjust the shunts (and magnet names) are D:Q104RF (D1Q4/D6Q4), D:Q304RF (D3Q4/D2Q4), and D:Q504RF (D5Q4/D4Q4).
5. There are three 50A shunts on Q5 magnets in the 10, 30 and 50 sectors. D:Q105RF (D1Q5), D:Q305RF (D3Q5), and D:Q505RF (D5Q5).

All of the quad shunts on the D:QSS quads, with the exception of the Q5 shunts, are used to change the Debuncher tune. The shunts must be changed in specific calculated ratios, which we call mults, in order to change the tune in a controlled manner. There are two separate mults: one for changing the horizontal tune and one for changing the vertical tune. These mults have been set up on P60 DEB10 subpages 9 and 10, with comments to help the user determine the direction and amplitude of change that will have to be made in order to move the tunes by a given amount.

When changing the shunt mults, there are a few things to remember. If large changes, on the order of multiple amps, are made to the shunts, then a Pbar expert should be notified to determine if cycling the Debuncher busses is in order. A Pbar expert should also be consulted if a tune change is required that is beyond the range of the shunts. The maximum value for each shunt is listed in the parameter description, and the minimum shunt value is zero. If the shunts are ranged out, then Pbar experts may choose to change D:QSS to give the shunts more range. However, there are further complications due to the Q5 magnets. Two of them are large quads with trims that are not on the D:QSS circuit, four of them are quads on the D:QSS of which three have shunts that are not part of the tune mult. Due to the complexity of this change, if the shunts are ranged out, the Pbar expert may choose instead to operate at a different spot on the tune diagram.

After the tune mults are used to set the Debuncher tunes to their nominal values of $\nu_x = 9.77$ and $\nu_y = 9.765$., some Pbar experts like to fine tune the tune values to try to find the absolute best spot for beam. This can be accomplished by changing the tune mults to move the tunes by small amounts to either side of the default values. Successive "add trace to plots" from the "Sanalyzer Display" page P42 for various tunes settings are compared. It is believed that the sideband peaks will get larger when there is more beam and get smaller when you are approaching resonance lines. If you move the tunes far enough, you will pass through a resonance line. If this happens, you will see the sideband peaks get smaller as you go through the resonance line and then get larger again after you are past the resonance line. Picking the value of the largest sideband near the default tune should be the best spot for beam.

We have given an accelerator physics background of what a tune is, and provided motivation on why we need to change them. We showed on the resonance diagram with the default Debuncher tunes of $\nu_x = 9.77$ and $\nu_y = 9.765$, and talked about the effect of resonance lines and higher order effects. We covered how we can determine the Debuncher tune by measuring a betatron sideband frequency with a spectrum analyzer connected to a Schottky pickup in the tunnel. We then covered what quadrupoles exist in the Debuncher and discussed how we change specific quadrupole shunts in predetermined mults to move the tunes. We are now ready to move on to the procedure.

Setup:

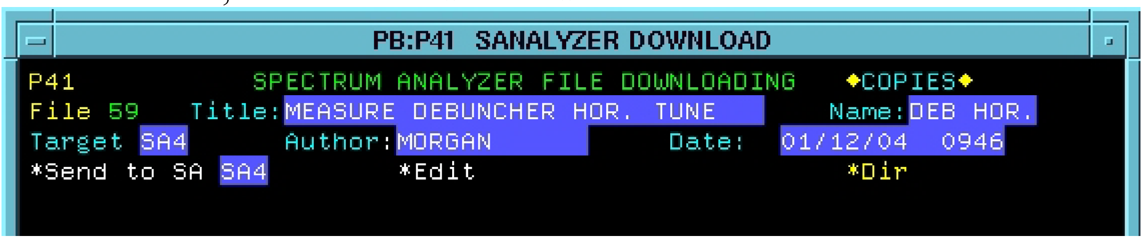
You will need spectrum analyzer #4 or #5 to complete this exercise. This exercise can be completed either remotely or at AP10. Verify that nobody is using SA #4 for other common tasks like measuring the Accumulator tunes. It is also a good idea to check with tuners and studiers in the MCR and AP10 before beginning. Acnet page D15 will show if the AP10 consoles (12, 13, 14) are in use, or call AP1 control room at extension x4370. Stacking can proceed normally during the tune measurements and adjustments.

Full Length Procedure:

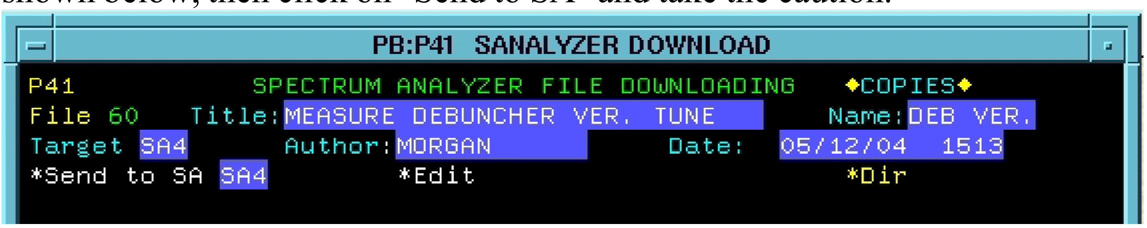
The following steps should be completed to measure the Debuncher Tunes. This section contains screen captures and detailed discussion. If you are already familiar with this procedure and would prefer to review a condensed version of this procedure, then click here. The numbers listed here assume the February 2005 default tune values of $\nu_x = 9.764$ and $\nu_y = 9.785$.

You can either look at each plane separately using a single spectrum analyzer, or you can look at both planes at the same time using two spectrum analyzers. The vertical tunes are much easier to see than the horizontal, so it is recommended to look at the vertical first.

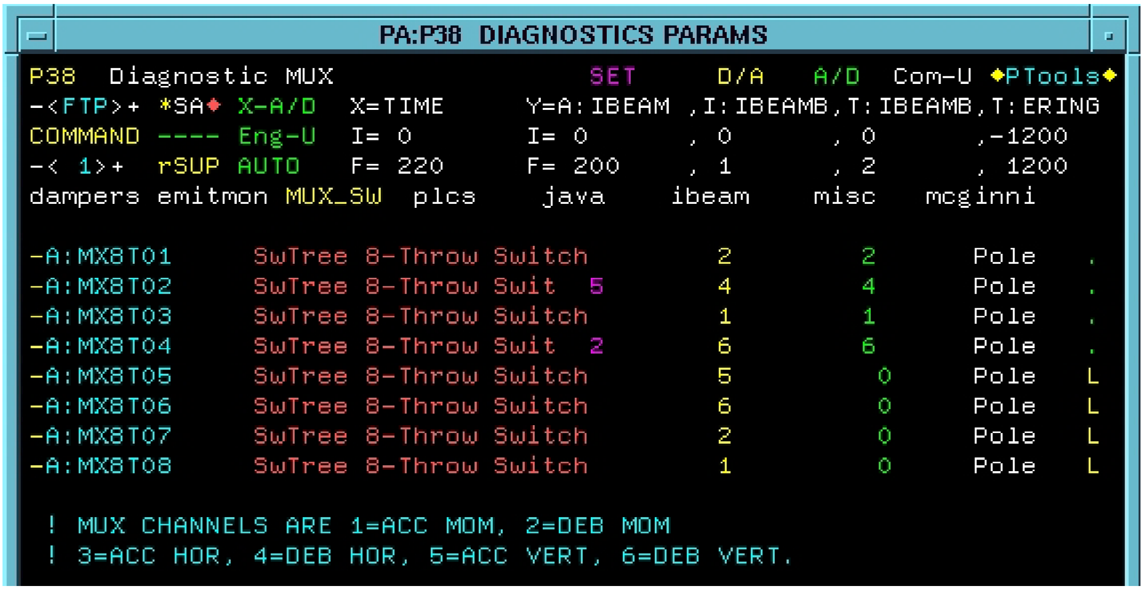
1. From P41 load the tune file.
    a. If you want to look at the Horizontal tune, then load file #59 to SA#4 (or SA #5). To do this, type 59 next to "File" as shown below and then interrupt. Verify SA4 (you can change this to SA5 if you wish to use SA #5 instead) is to the right of "Send to SA" as shown below, then click on "Send to SA" and take the caution.



    b. If you want to look at the Vertical Tune, then load file #60 to SA #4 (or SA #5). To do this, type 60 next to "File" as shown below and then interrupt. Verify SA4 (you can change this to SA5 if you wish to use SA #5 instead) is to the right of "Send to SA" as shown below, then click on "Send to SA" and take the caution.



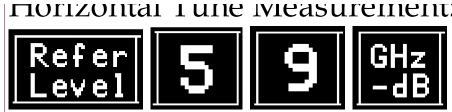
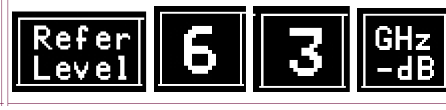
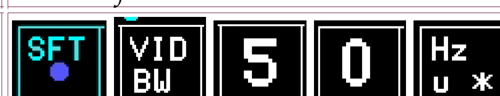
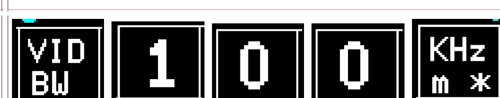
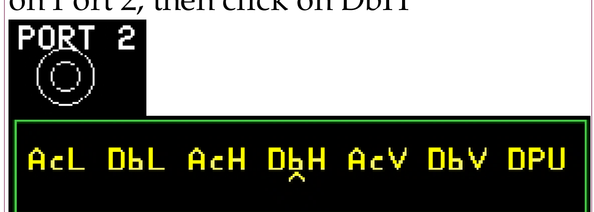
    c. Currently you will get an "Illegal SA for Mux" error when loading the P41 file. This error occurs because the P41 command that connects Spectrum Analyzer Port 2 (the default port on SA #4 and SA #5) to the correct Schottky pickup currently does not work. Until it does work, we will have to connect the Spectrum Analyzer to the Schottky locally, via the SA emulator (see Step 2 below), or by setting the appropriate switch tree parameter from P38 Diagnostic MUX <1>.
        i. Spectrum Analyzer #4: Set A:MX8T02 to 4 for Debuncher Horizontal Schottky or 6 for Debuncher Vertical Schottky.
        ii. Spectrum Analyzer #5: Set A:MX8T04 to 4 for Debuncher Horizontal Schottky or 6 for Debuncher Vertical Schottky .



iii. In the above example, SA #4 is set to the Horizontal Schottky pickup and SA #5 is set to the Vertical Schottky pickup. The value that you set depends on which Schottky pickup you want to connect to which Spectrum Analyzer.

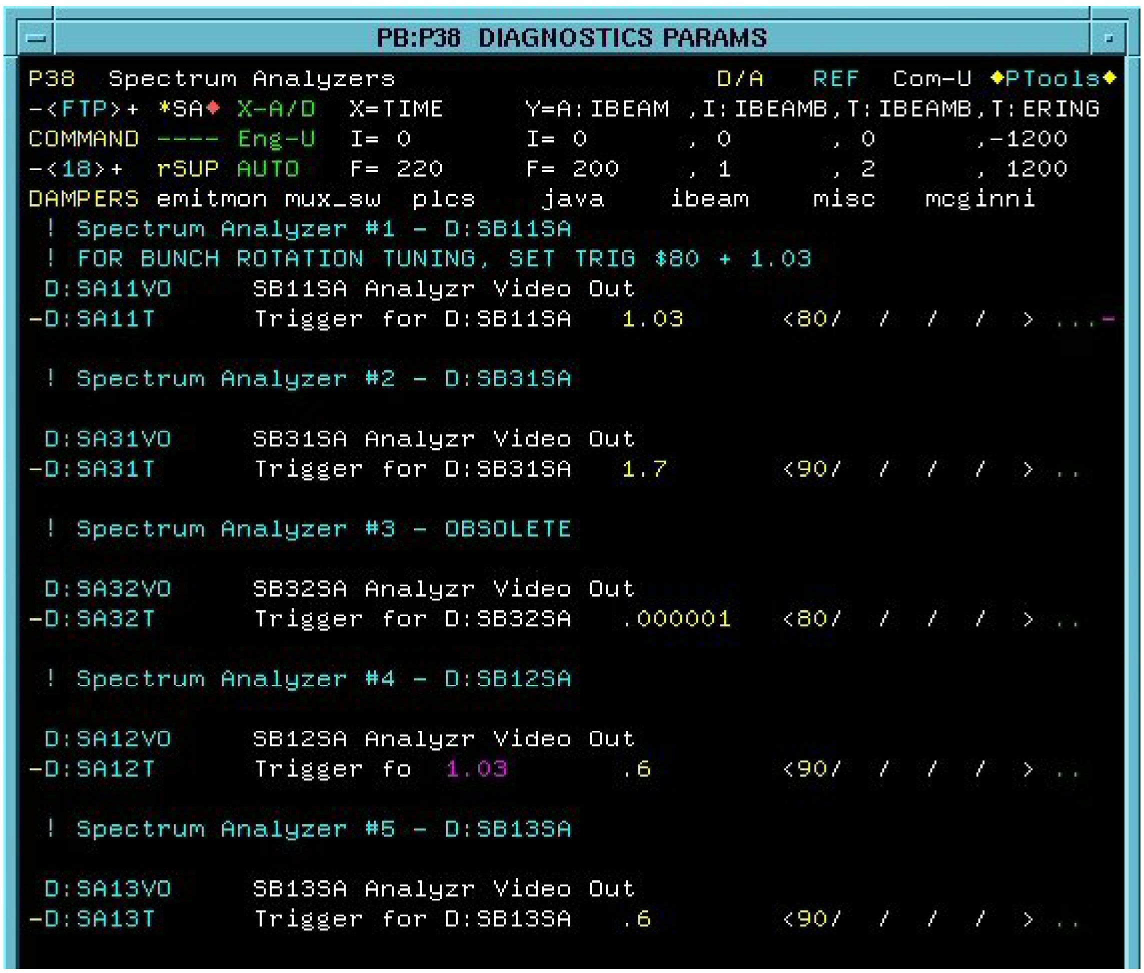
2. If the P41 file does not load properly, you can setup Spectrum Analyzer #4 or Spectrum Analyzer #5 through P42 or the Spectrum Analyzer emulator. The below table shows how to setup Spectrum Analyzer #4 or Spectrum Analyzer #5 from P42 or SA emulator commands. These are the same commands that are loaded above in P41 File #59 (or #60).

Command	P42 Commands	Emulator Commands
Connect to SA #4 or SA #5.	Go to P42, select SA #4 (D:SBSB12A) or SA #5 (D:SB13SA) and enter data into the SET DATA field.	Go to P42, click on ♦Emulate♦ located at the top right-hand portion of the screen, and then select Spectrum Analyzer #4 or Spectrum Analyzer #5.
Instrument Preset	IP	INS PST
Set the Resolution Bandwidth	RB 1 KZ	RES BW 1 KHz m *
Set the Frequency Span	SP 50 KZ	Freq Span 5 0 KHz m *
Set a Log Scale	LG 2 DB	LOG dB/ 2 MHz +dB
		Horizontal Tune Measurement:

Set the Reference Level	Horizontal Tune Measurement: RL -59 DB Vertical Tune Measurement: RL -63 DB	Horizontal Tune Measurement:  Vertical Tune Measurement: 
Set the Center Frequency. We use the lower sideband for horizontal and the upper sideband for vertical.	Horizontal Tune Measurement: CF 73.89145 MZ Vertical Tune Measurement: CF 74.80540 MZ	Horizontal Tune Measurement:  Vertical Tune Measurement:  *Note: You may notice that the number used above is one significant digit less than what we send with P41 or P42. This is due to a limitation of the emulator SA. This value will work as it only corresponds to a small offset on the Spectrum Analyzer display. If you want to enter the exact center frequency value, use the P42 "set data" field as shown on the left.*
Set Video Average	KSG 50	
Set Video Bandwidth	VB 100 HZ	
Connect the Spectrum Analyzer port 2 to the Schottky Pickup. *Note: Port 2 is*	Horizontal Tune Measurement: SIG: MUX4 2 Vertical Tune Measurement: SIG: MUX6 2 *NOTE: This command does not*	Horizontal Tune Measurement: Click on Port 2, then click on DbH  Vertical Tune Measurement: Click on Port 2, then click on DbV

the default on both SA #4 and SA #5.	*current load from P41 or P42. Use the SA emulator or set manually from a parameter page as outlined in step 1.c.*	Port 2, then click on DbV 

3. We must now set the Spectrum Analyzer trigger timer to trigger at $90 + 0.6 seconds. This time was chosen because it is after the bunch rotation process has been completed, but before the stochastic cooling system has had a chance to cool the beam which reduces the size of the signal. The trigger timers can be found on P38 Spectrum Analyzers <18> as shown below. D:SA12T is the Spectrum Analyzer #4 trigger and D:SA13T is the Spectrum Analyzer #5 trigger.



5. You can view the Spectrum Analyzer traces on the CATV system.
   a. Spectrum Analyzer #4: CATV AP 21
   b. Spectrum Analyzer #5: CATV AP 22
6. From P42 start the SA Emulator by clicking on  in the upper right corner of the screen. Chose either Spectrum Analyzer #4 or Spectrum Analyzer #5, depending on which Spectrum Analyzer you are using.

7. Leave P42 open, since we will be using to make our screen plots.
8. The sideband signal that we are trying to measure can be very small and hard to pick out from the noise. This is especially true of the horizontal signal. The following steps allow us to see the sideband frequency.

    a. On the SA Emulator, click the CLR WRT button for trace A. This ensures that our plot only has data from our intended sample. This is especially important since the signal that we are measuring is very small and the we are averaging for up to 50 cycles.
    b. Wait for up to 50 stacking cycles to get a good data sample.
    c. The sideband signal may still not be obvious on Spectrum Analyzer trace. We can display the cumulative trace and turn off video averaging on the Spectrum Analyzer to make the sideband signal stand out. To do this, on the SA Emulator, click the VW button (for the A trace), followed by SFT, and then SWP TIM. The trace should "freeze" and the peak should be visible.
    d. If you cannot see a clear peak, then try turning off the Debuncher transverse cooling in the plane that you are making the measurement, then repeat steps 8.a-8.d above. Make sure to turn the cooling back on after you have completed your measurement.
    e. If you still cannot see the peak, try widening the frequency span on the Spectrum Analyzer emulator. If that does not work, then you should contact a Pbar expert for further assistance.
9. Once we have our sideband peak displayed, we need to measure the sideband frequency, which is the frequency that corresponds to the peak of the spectrum analyzer distribution. This can be done by doing the following:

    a. In the Marker Section, click on NRM, followed by PK SRC Peak Search.
    b. Verify that the marker shown on CATV AP #21 (if your are using SA #4) or CATV AP #22 (if you are using SA #5) is aligned with the peak of the distribution.
    c. If the marker is not aligned with the peak, then adjust the marker location by clicking on NRM, followed by KNOB Hi. Use the console knob to move the marker until it aligns with the peak of the distribution.
    d. To read the marker frequency, click on Read which is located in the lower right of the keystroke history window.
    e. Note the value Mrkr freq = in the keystroke history. This is the sideband frequency that we will use to calculate the tune.

10. From P42, select "Start a new plot" and then click on "Trace A." When the tunes are at their

default values, the peaks should be located in the center of the spectrum analyzer display. Figures 2 shows a horizontal tune measurement and figure 3 shows a vertical tune measurement.

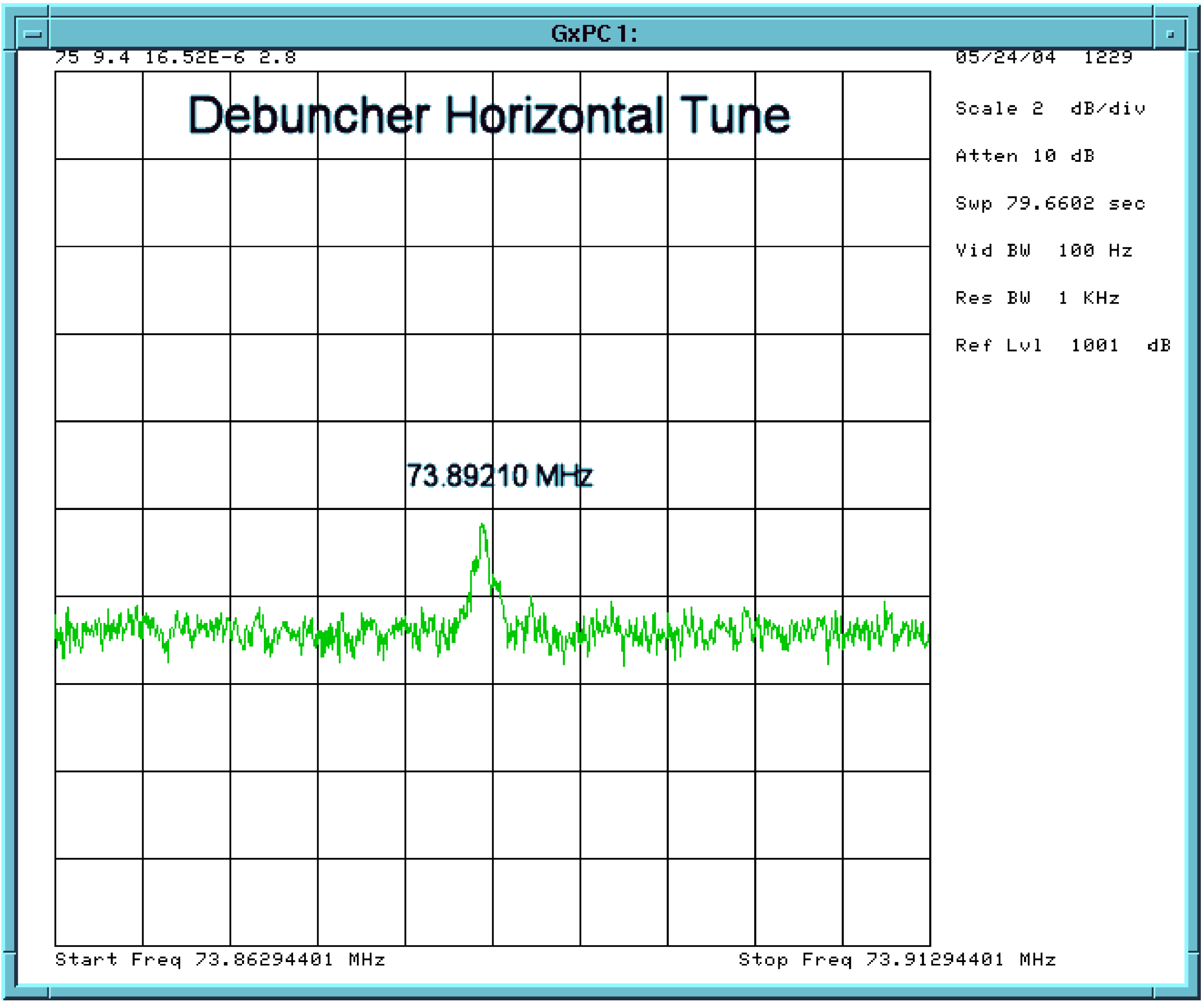


Figure 4: The December 2005 default horizontal tune is $\nu_x = 9.77$ which corresponded to 73.88680 MHz on the spectrum analyzer. As of February 2005, we were running closer to $\nu_x = 9.764$, which would correspond to 73.89145 on the spectrum analyzer.

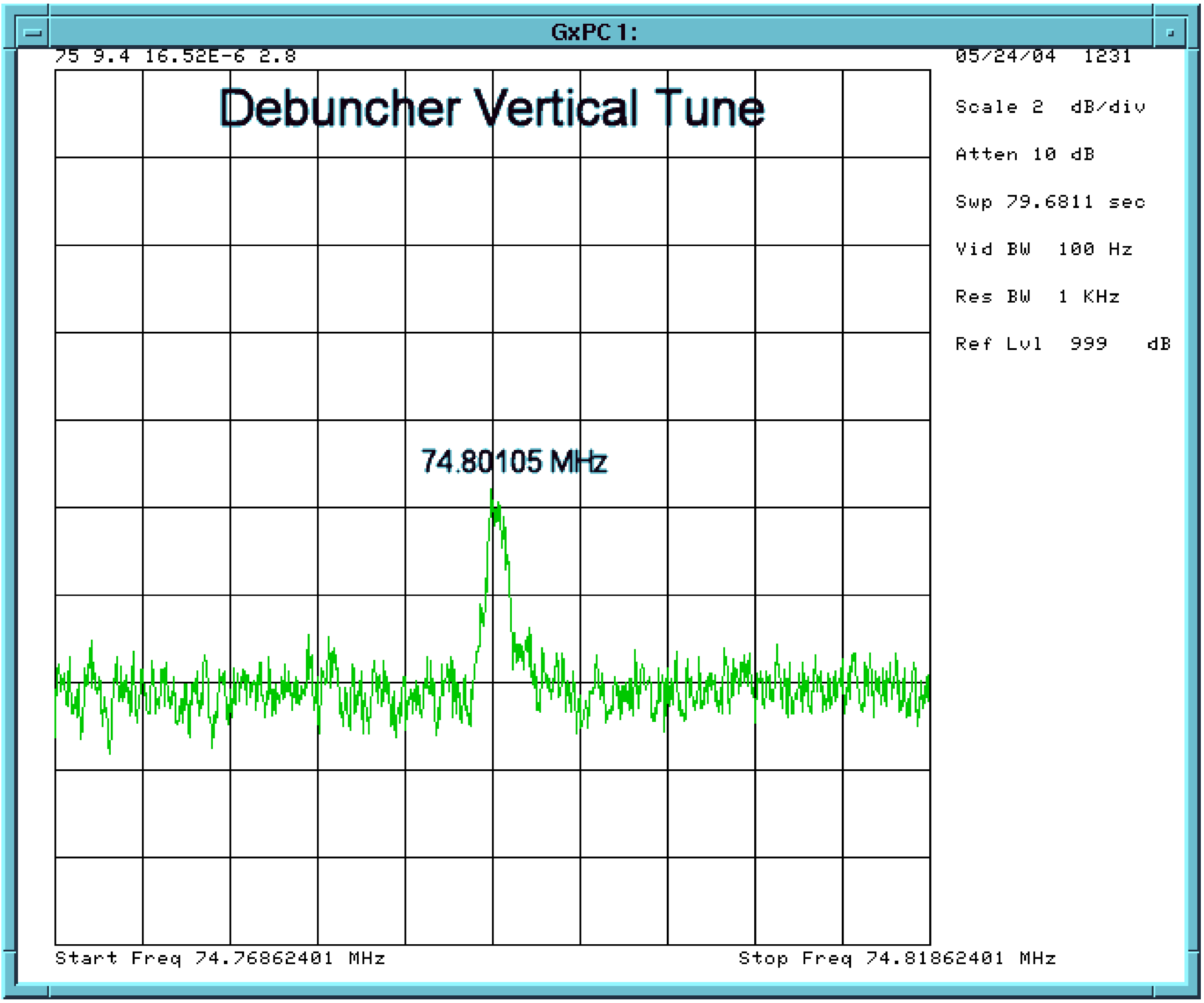


Figure 5: The December 2005 default vertical tune is $\nu_y = 9.765$ which corresponds to 74.80105 MHz on the spectrum analyzer. As of February 2005, we were running closer to $\nu_y = 9.785$, which would correspond to 74.805 on the spectrum analyzer.

11. We calculate the tunes from equations (1.8) and (1.9) from the background section of this document. We will assume that DRF and the Debuncher Momentum Cooling keeps the revolution frequency of the beam (f_{rev}) close to 590018 Hz. The sideband frequency (f_s) is the peak frequency on the Spectrum Analyzer determined in step 9 above.

    a. If you are measuring the horizontal tune (ν_x), then the fraction portion of the horizontal tune is calculated from $\nu_x = 126 - \frac{f_s}{590018}$.
    b. If you are measuring the vertical tune (ν_y), then the fractional portion of the vertical tune is calculated from $\nu_y = \frac{f_s}{590018} - 126$.
    c. Note: if you would like a shortcut to calculating the tune, then you can use the

Manual Debuncher Tunes spreadsheet calculator at http://www-bdnew.fnal.gov/pbar/organizationalchart/drendel/Projects/Studies-Spreadsheets/Manual-Debuncher-Tunes.xls. To use this spreadsheet, simply enter in the horizontal and vertical sideband frequency measurements into their respective cells. The spreadsheet then calculates the tunes.

i. Figure 5a shows what the spreadsheet looks like when you enter the page

Manual Debuncher Tune Measurement		
http://www-bdnew.fnal.gov/pbar/documents/TuningGuide/Debuncher-Tunes/Debuncher-tu		
Step #1: Enter Longitudinal Shottky Peak Value (Optional)		Fal
If you chose not to measure this value, just enter 74.93229 for the schottky peak		Typ
Longitudinal Schottky Peak (MHz) =	74.93229	74.
Harmonic =	127	127
Revolution Frequency (Hz) =	590018.0	590
Step #2: Enter the sideband peak values		Fal Typ
Horizontal Sideband (MHz) =		73.
Vertical Sideband (MHz) =		74.
Step #3: The tune values are automatically calculated		200 Tur
Horizontal Tune (Ave) =	**126**	0.7
Vertical Tune (Ave) =	**-126**	0.7

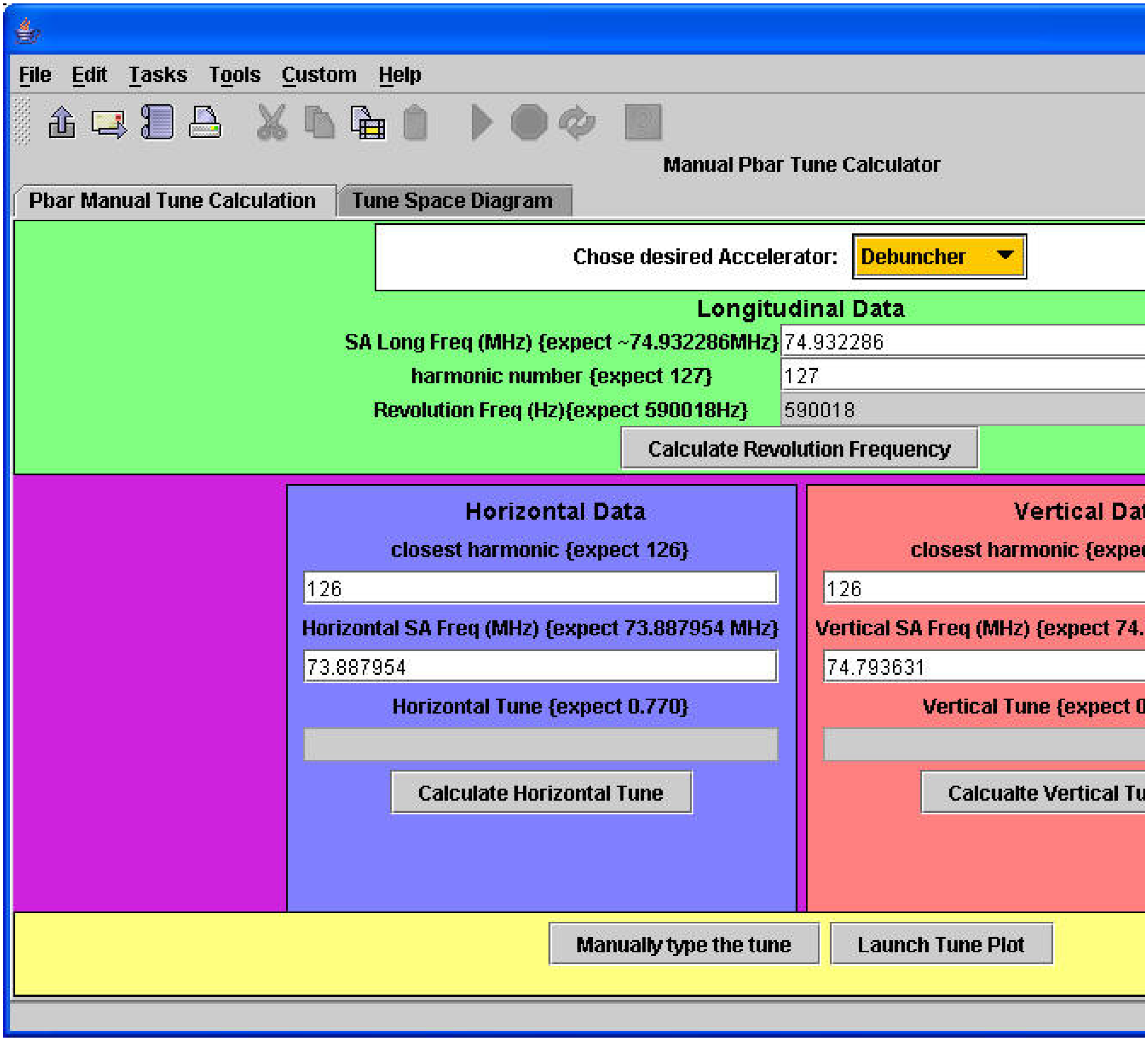
ii. Figure 5b shows the spreadsheet after entering values for the horizontal and vertical sideband.

Manual Debuncher Tune Measurement	
http://www-bdnew.fnal.gov/pbar/documents/TuningGuide/Debuncher-Tunes/Debun	
Step #1: Enter Longitudinal Shottky Peak Value (Optional)	
If you chose not to measure this value, just enter 74.93229 for the schottky peak	
Longitudinal Schottky Peak (MHz) =	74.93229
Harmonic =	127
Revolution Frequency (Hz) =	590018.0
Step #2: Enter the sideband peak values	
Horizontal Sideband (MHz) =	73.89145
Vertical Sideband (MHz) =	74.8054
Step #3: The tune values are automatically calculated	
Horizontal Tune =	**0.7641**
Vertical Tune =	**0.7849**

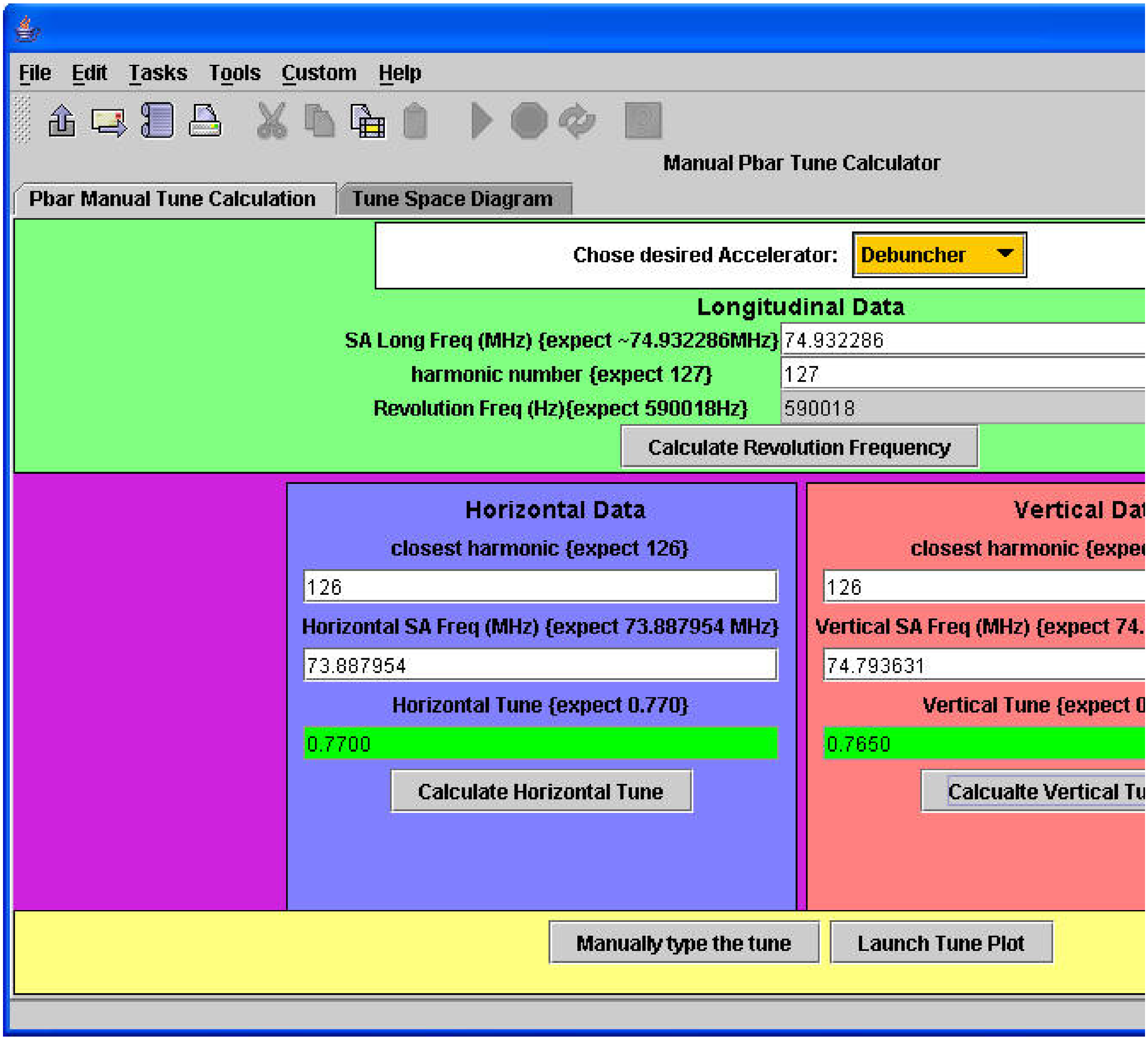
iii. In this example, 73.89145 was entered as the horizontal sideband frequency and 74.8054 was entered as the vertical sideband frequency. The tunes were then calculated to be 0.7641 and 0.7849.

d. Note: There is also a Java application tool that is being developed to help make calculating the Debuncher tunes easier.

   i. To launch this application, simply go to http://www-bd.fnal.gov/appix/start?p=50000180&n=45000585.



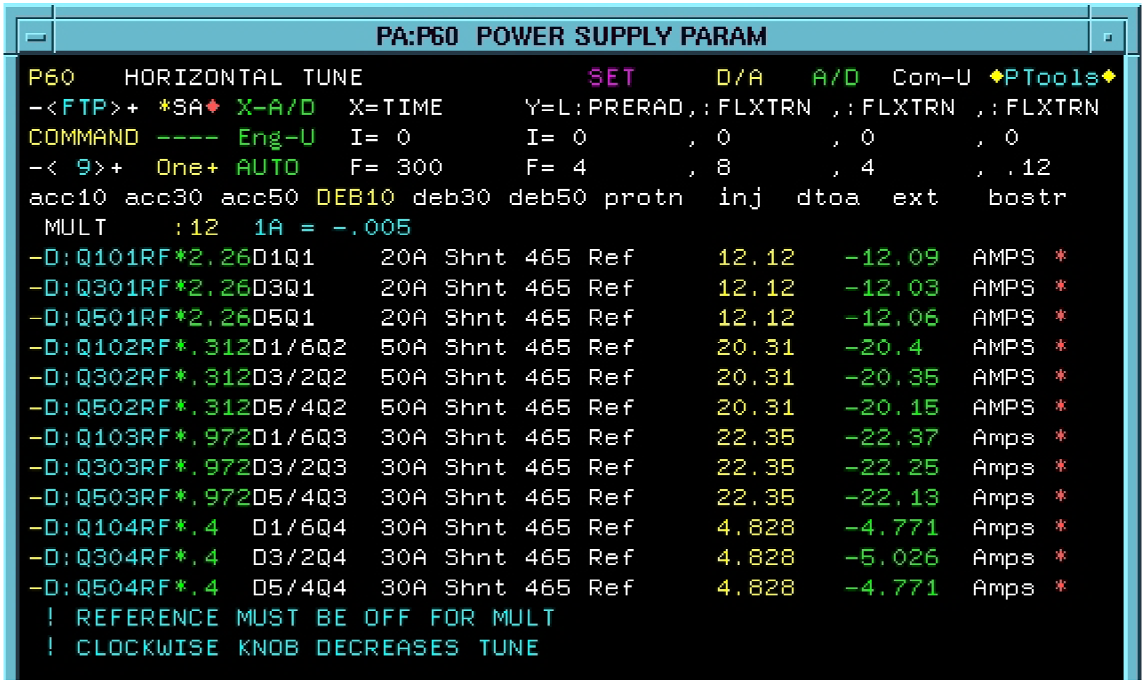
   ii. Next, simply enter in the horizontal sideband peak frequency and then click "Calculate Horizontal Tune", or enter the vertical sideband peak frequency and then click "Calculate Vertical Tune."



iii. The application then displays the tunes. If they are in tolerance, they are displayed with a green background. If they are off by enough to consider making a change, then they are displayed with a yellow background. If they are off by enough to consider contacting an expert, then they are displayed with a red background.

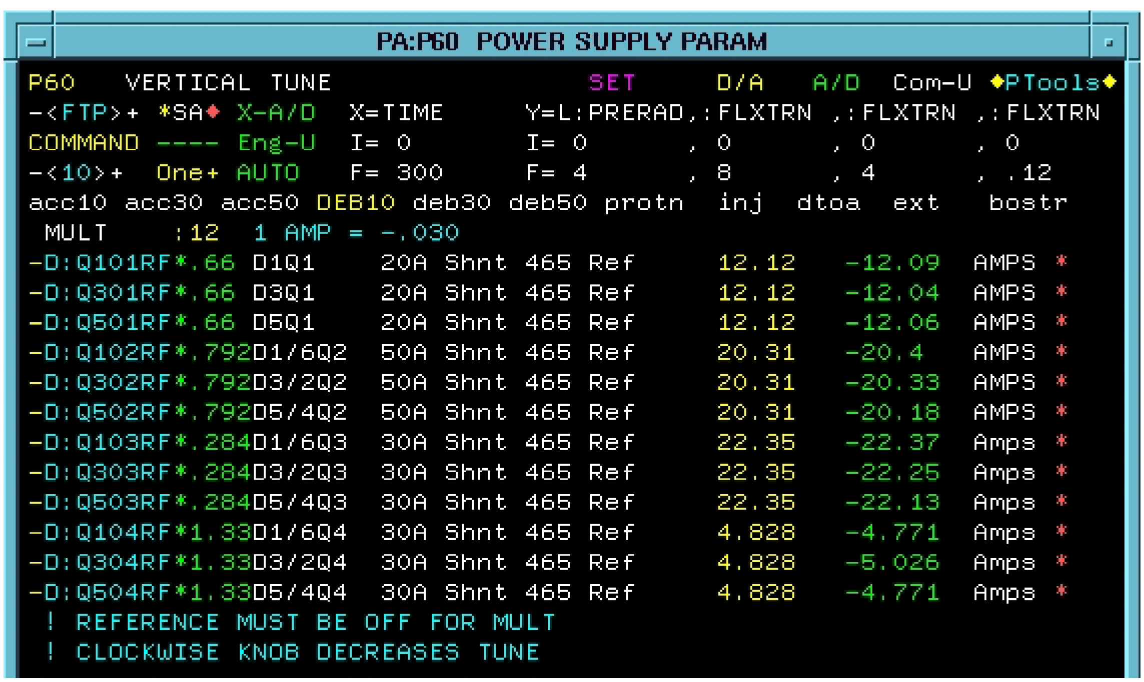
12. Tune mults have been set up on P60 DEB10 subpages <9> and <10> as shown in Figure 6 and 7 below. Before adjusting the tunes, you should note the following:
   a. The Debuncher tune mults have minimal affect on the tunes in the other plane.
   b. As noted at the top of each page, a +1 Amp change *to the D/A* of the top element of the mult results in a –.005 change when changing the horizontal mult and -0.03 change when tuning the vertical mult. This is a bit confusing since the D/A's are positive and

the A/D's are negative. A larger absolute value of the D/A and A/D results in a negative tune change. *For both mults a clockwise knob rotation results in a negative tune change.*



```
PA:P60  POWER SUPPLY PARAM
P60    HORIZONTAL TUNE                SET      D/A    A/D   Com-U ♦PTools♦
-<FTP>+ *SA♦ X-A/D  X=TIME      Y=L:PRERAD,:FLXTRN ,:FLXTRN ,:FLXTRN
COMMAND ---- Eng-U  I= 0        I= 0        , 0        , 0        , 0
-< 9>+  One+ AUTO   F= 300      F= 4        , 8        , 4        , .12
acc10 acc30 acc50 DEB10 deb30 deb50 protn  inj  dtoa  ext   bostr
 MULT     :12   1A = -.005
-D:Q101RF*2.26D1Q1     20A Shnt 465 Ref      12.12   -12.09   AMPS *
-D:Q301RF*2.26D3Q1     20A Shnt 465 Ref      12.12   -12.03   AMPS *
-D:Q501RF*2.26D5Q1     20A Shnt 465 Ref      12.12   -12.06   AMPS *
-D:Q102RF*.312D1/6Q2   50A Shnt 465 Ref      20.31   -20.4    AMPS *
-D:Q302RF*.312D3/2Q2   50A Shnt 465 Ref      20.31   -20.35   AMPS *
-D:Q502RF*.312D5/4Q2   50A Shnt 465 Ref      20.31   -20.15   AMPS *
-D:Q103RF*.972D1/6Q3   30A Shnt 465 Ref      22.35   -22.37   Amps *
-D:Q303RF*.972D3/2Q3   30A Shnt 465 Ref      22.35   -22.25   Amps *
-D:Q503RF*.972D5/4Q3   30A Shnt 465 Ref      22.35   -22.13   Amps *
-D:Q104RF*.4   D1/6Q4  30A Shnt 465 Ref      4.828   -4.771   Amps *
-D:Q304RF*.4   D3/2Q4  30A Shnt 465 Ref      4.828   -5.026   Amps *
-D:Q504RF*.4   D5/4Q4  30A Shnt 465 Ref      4.828   -4.771   Amps *
 ! REFERENCE MUST BE OFF FOR MULT
 ! CLOCKWISE KNOB DECREASES TUNE
```

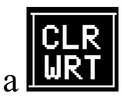
Figure 6: This is the horizontal tune mult. A clockwise knob increases the shunt D/A which lowers the tune. A 1 amp change will change the tune by approximately -0.005.



```
PA:P60  POWER SUPPLY PARAM
P60    VERTICAL TUNE                  SET      D/A    A/D   Com-U ♦PTools♦
-<FTP>+ *SA♦ X-A/D  X=TIME      Y=L:PRERAD,:FLXTRN ,:FLXTRN ,:FLXTRN
COMMAND ---- Eng-U  I= 0        I= 0        , 0        , 0        , 0
-<10>+  One+ AUTO   F= 300      F= 4        , 8        , 4        , .12
acc10 acc30 acc50 DEB10 deb30 deb50 protn  inj  dtoa  ext   bostr
 MULT     :12   1 AMP = -.030
-D:Q101RF*.66 D1Q1     20A Shnt 465 Ref      12.12   -12.09   AMPS *
-D:Q301RF*.66 D3Q1     20A Shnt 465 Ref      12.12   -12.04   AMPS *
-D:Q501RF*.66 D5Q1     20A Shnt 465 Ref      12.12   -12.06   AMPS *
-D:Q102RF*.792D1/6Q2   50A Shnt 465 Ref      20.31   -20.4    AMPS *
-D:Q302RF*.792D3/2Q2   50A Shnt 465 Ref      20.31   -20.33   AMPS *
-D:Q502RF*.792D5/4Q2   50A Shnt 465 Ref      20.31   -20.18   AMPS *
-D:Q103RF*.284D1/6Q3   30A Shnt 465 Ref      22.35   -22.37   Amps *
-D:Q303RF*.284D3/2Q3   30A Shnt 465 Ref      22.35   -22.25   Amps *
-D:Q503RF*.284D5/4Q3   30A Shnt 465 Ref      22.35   -22.13   Amps *
-D:Q104RF*1.33D1/6Q4   30A Shnt 465 Ref      4.828   -4.771   Amps *
-D:Q304RF*1.33D3/2Q4   30A Shnt 465 Ref      4.828   -5.026   Amps *
-D:Q504RF*1.33D5/4Q4   30A Shnt 465 Ref      4.828   -4.771   Amps *
 ! REFERENCE MUST BE OFF FOR MULT
 ! CLOCKWISE KNOB DECREASES TUNE
```

Figure 7: This is the vertical tune mult. A clockwise knob increases the shunt D/A which lowers the tune. A 1 amp change will change

the tune by approximately -0.03.

13. Adjust the Debuncher tune in the plane that you are looking at form the mults in Figures 4 and 5. The default tune values during 2004 were $\nu_x = 9.77$ and $\nu_y = 9.765$. The default tune values as of February 2005 are $\nu_x = 9.764$ and $\nu_y = 9.785$.
    a. Verify that you have enough range in each of the shunts before you make the change. The minimum value of each shunt is zero, and the description field of the parameter tells you the maximum value of the shunt (20A, 30A, or 50A). If there is not enough range in the shunts, then a Pbar expert should be consulted since a change to D:QSS would be required to give the shunts more range. A Pbar expert can help determine if that change is necessary of if we should run at a different set of tune values.
    b. Adjust the tunes toward their default values. The center of the spectrum analyzer corresponds to the default tune value.
    c. Repeat steps 8-12 after each tune change is made. Make sure to do a 

on the SA Emulator in between each measurement.
    d. When you have completed one plane (horizontal or vertical), then repeat this procedure for the other plane.
    e. If you need to make more than a 0.5 amp change, then do the changes in multiple steps.
    f. If you need to make more than a 1 amp change, then contact a Pbar expert to determine if cycling the Debuncher busses will be necessary.
14. Once the tunes are set to the default values, you may wish to explore the tune space in the immediate vicinity of the default values to find the optimal tune values for the current beam conditions. To do this, once you have completed steps 1-12 above, do the following:
    a. Pick a plane (horizontal or vertical)
    b. Make sure to have the P42 plot at the default tune value, for the plane you are looking at (horizontal or vertical), from step 12.
    c. Make a small tune change from the mults in Figures 6 or 7.
    d. Do a 

on the SA Emulator.
    e. Repeat Step 8 to display the sideband signal.
    f. From P42 toggle "Add trace to plot" and then click "Trace A."
    g. Compare the height of the newly measured sideband peak with the sideband peak taken at the nominal tune value.
        i. If the newly measured sideband sideband peak is larger, move the tune more in the same direction.
        ii. If the newly measured sideband sideband peak is smaller, move the tune in the other direction.
    h. Repeat steps 14.c through 14.g until you find a peak, keeping in mind the following:
        i. Make sure that you have the same number of beam pulses for each data sample.
        ii. Make sure to make only small tune changes when tuning with this method.
        iii. If you move the tunes far enough, you will pass through a resonance line. If this

happens, you will see the sideband peaks get smaller as you go through the resonance line and then get larger again after you are past the resonance line.

iv. Pick the tune value that corresponds to the highest sideband peak on the distribution and corresponds to the best stacking. See Examples 1 through 3 in figures 8 through 12 below.

i. Repeat for the other plane (vertical or horizontal).

15. Document any tuning changes in the Pbar electronic log book.

Example #1: Figure 8 shows a vertical tune scan showing showing how the peak of the sideband signal varies with the tune. The cyan trace represents a good running point.

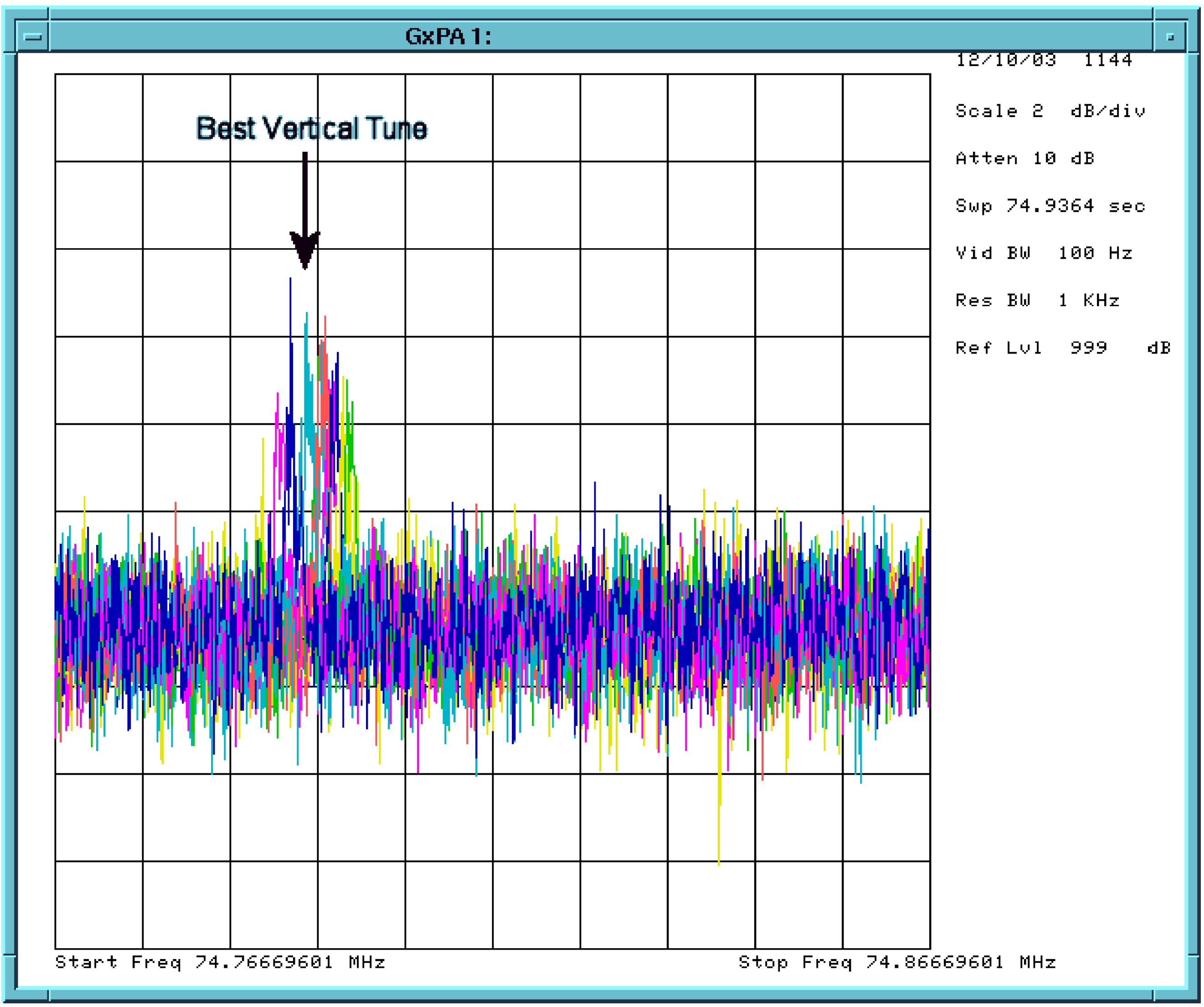


Figure 8: Fine-tune movement of the tunes. Pick the value of the tunes that corresponds to the largest sideband signal. One could argue that I should have chosen the dark blue peak to the left; however, the center of the distribution appears to be closer to the cyan trace.

Example #2: Figures 9 and 10 show the results of a Debuncher vertical tune scan. Figure 9 shows the sideband signals during the scan and Figure 10 shows the corresponding tune space diagram. The 3/4 is a narrow but strong resonance line. We can see that the sideband signal gets small if we are very close to it. There is also a bad vertical tune location around .769 where the peaks get smaller. On the resonance diagram in Figure 10, this is where the 13th order sum resonance lines are bunched closer together. A vertical tune of .758, which was between the two bad locations was chosen as a good operating point during this tune-up.

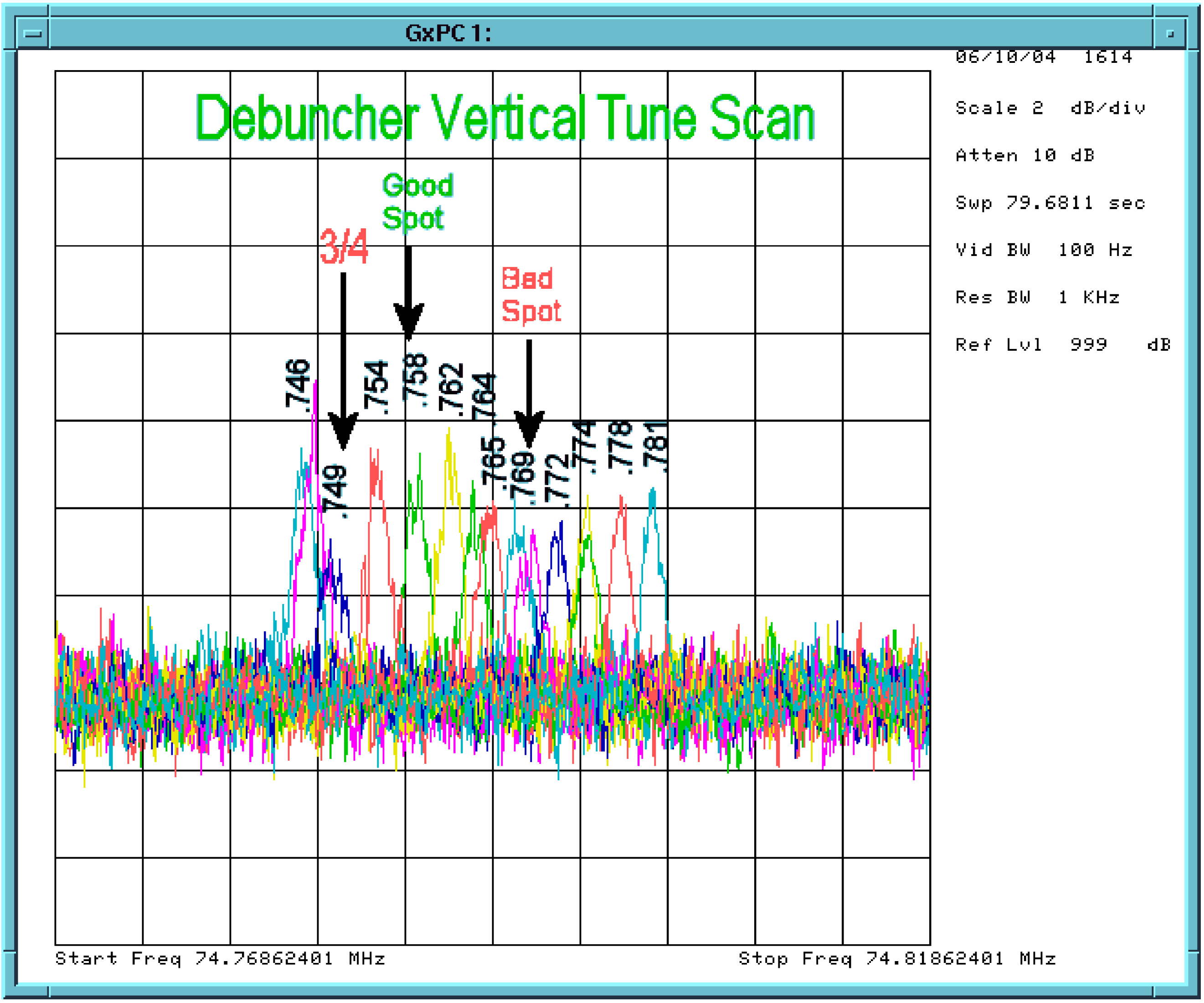


Figure 9: Vertical tune scan with $\nu_x = .772$. The sideband signal gets very small around the 3/4 resonance. There is also a location around ν_y=.769 where the sideband signals get weaker. Since we are assuming that a smaller sideband signal means less beam, we want to avoid these two locations in tune space. Vertical tunes close to ν_y=.758 provided a stable location in between the two bad locations in tune space.

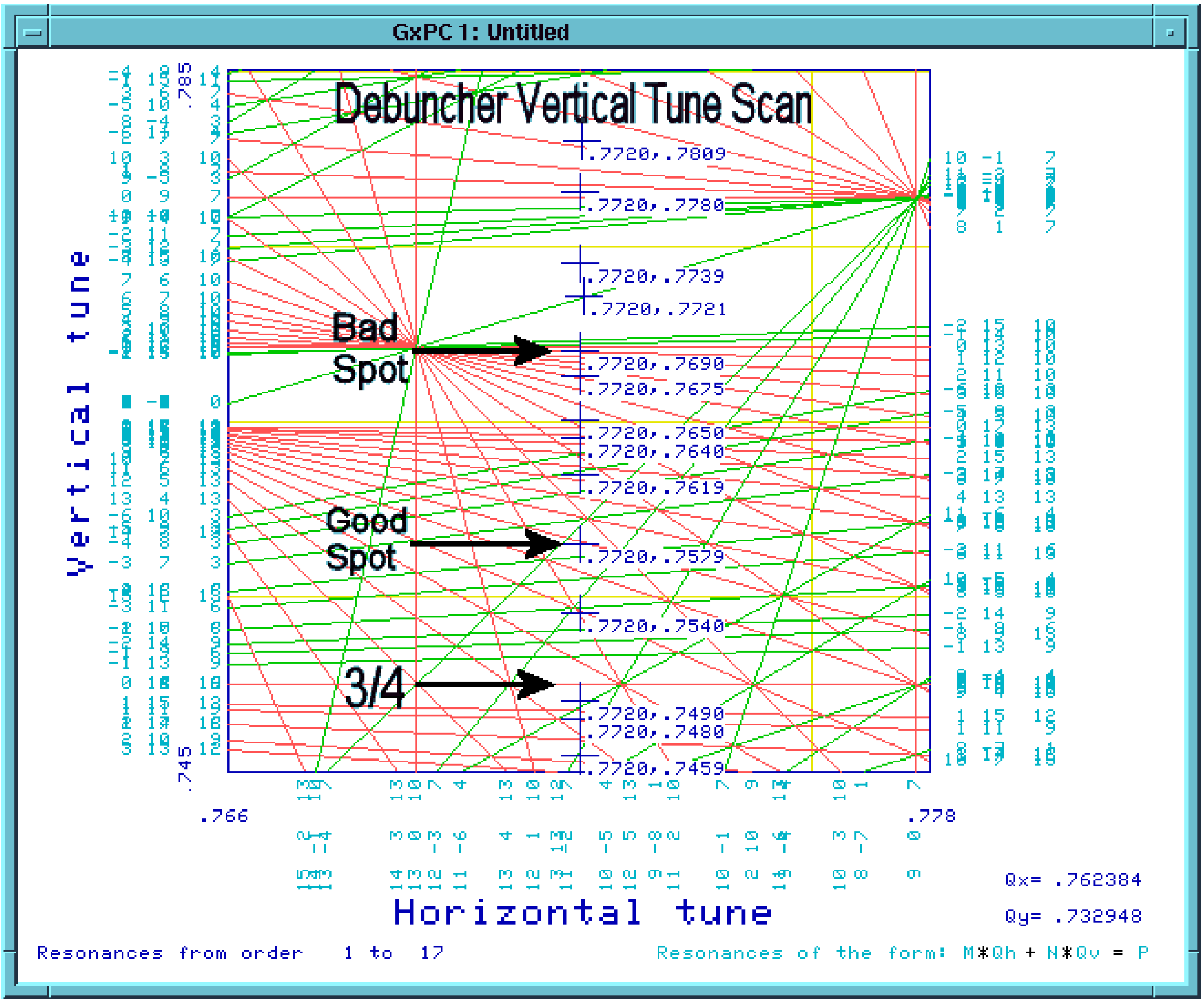


Figure 10: Tune space diagram showing the tunes during the vertical tune scan displayed in Figure 9.

Example #3: The tune space diagram is often not enough to determine the best operating point for the Debuncher tunes. Figures 11 and 12 show the correlation between the vertical sideband signal and the beam making it to the Accumulator. As the sideband peaks get larger, the amount of beam to the Accumulator increases. This is shown with Core 2-4 GHz Momentum TWT power.

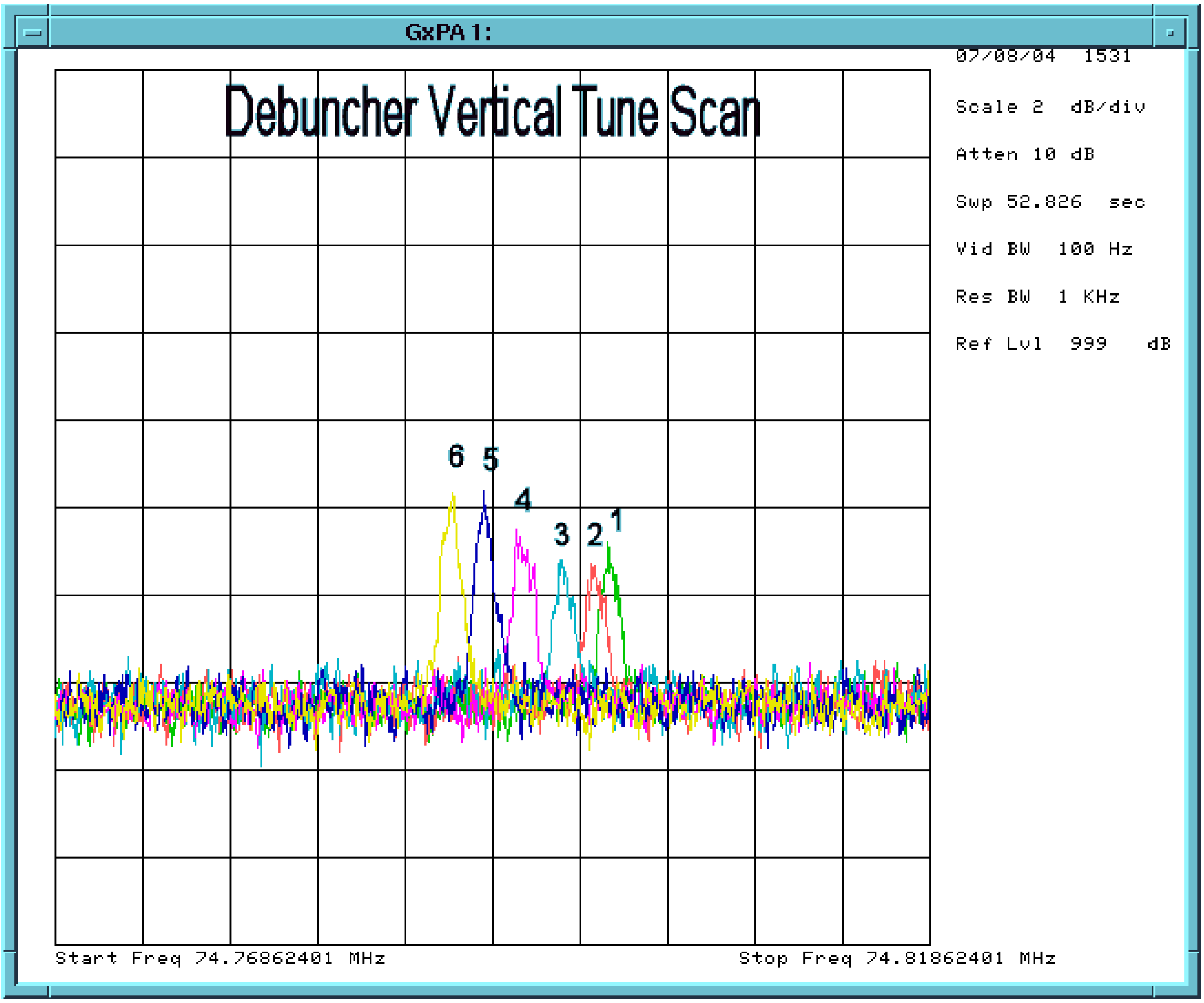


Figure 11: This is another vertical tune scan. Between the Cyan and Red traces is the narrow and strong 3/4 resonance. We see that beam is better on either side of the resonance line. The Blue and
Yellow traces represent the best beam, which in this case landed the vertical tune at .760. The numbers
1-6 on the diagram indicate the order of the vertical tune changes allow this figure to be compared with
Figure 10. Figure 10 below shows stack rate, production efficiency and core momentum cooling power
(indication of beam to the Accumulator) during the tune scan.

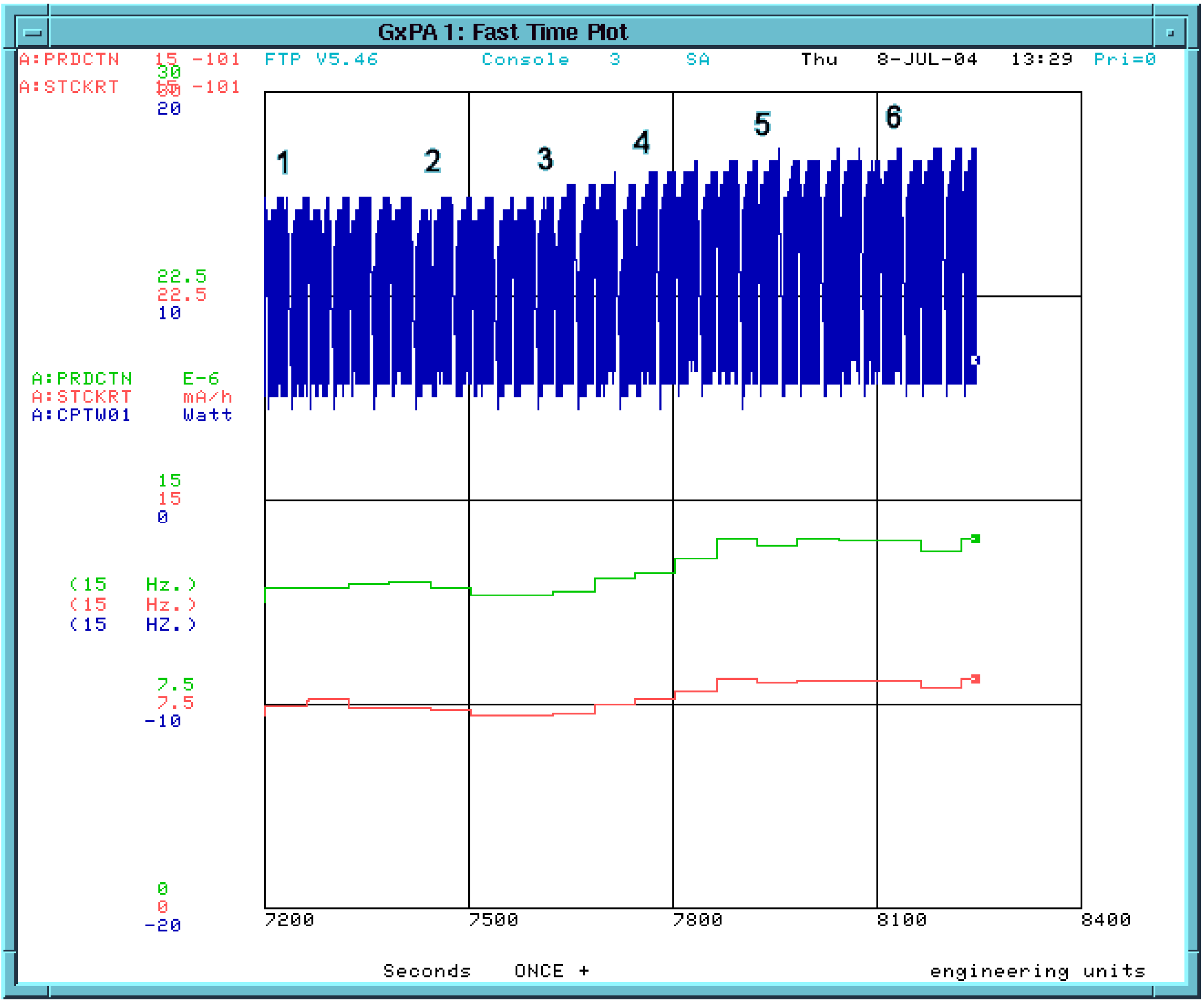


Figure 12: Stack rate, production efficiency and core momentum cooling power (indication of beam to the Accumulator) during the tune scan. The numbers 1-6 on this diagram correspond to the numbers 1-6 on Figure 11. We can see that when the sideband peaks are bigger in Figure 11, the core power, stack rate and production all increase.

Condensed Procedure:

The following is a condensed checklist of the steps covered in the above procedure. No screen captures nor motivating discussion are provided in this section. For more detail, discussion and screen captures, read the Full Length Procedure above.

1. From P41 load the tune file. There is one file for measuring the horizontal tune and another for measuring the vertical tune.
   a. Load file #59 to spectrum analyzer 4 or 5 to measure the horizontal tune.
   b. Load file #60 to spectrum analyzer 4 or 5 to measure the vertical tune.

2. Use the Spectrum Analyzer Emulator (started from P42) to connect Port 2 of the spectrum analyzer to the appropriate Schottky pickup
   a. Connect to DbH if you are measuring the horizontal tune.
   b. Connect to DbV if you are measuring the vertical tune.
3. Set the Spectrum Analyzer trigger timer to trigger at $90 + 0.6 seconds.
   a. D:SA12T is the Spectrum Analyzer #4 trigger
   b. D:SA13T is the Spectrum Analyzer #5 trigger.
4. You can view the Spectrum Analyzer traces on the CATV system.
   a. Spectrum Analyzer #4: CATV AP 21
   b. Spectrum Analyzer #5: CATV AP 22
5. On the SA Emulator, click the "Clear Write" button (for the A trace) to restart the data sampling.
6. Wait for up to 50 stacking cycles to get a good data sample.
7. On the SA Emulator, click the "View" button (for the A trace), followed by "Shift", and then "Sweep Time". The trace should "freeze" and the peak should be visible.
8. Turn on the marker by clicking on the "NRM" button , followed by the "Peak Search" button. If the marker is not on the peak, then adjust the marker location by clicking on the "NRM" button, followed by the "Knob Hi" button. Use the console knob to move the marker until it aligns with the peak of the distribution. Write Down the frequency where the marker located (this is the sideband frequency f_s).
9. Calculate the fractional portion of the tune from the following equations. f_s is the sideband frequency that was measured in the previous step. You can use the equations listed below, or simple use the manual tune calculator spreadsheet at http://www-bdnew.fnal.gov/pbar/organizationalchart/drendel/Projects/Studies-Spreadsheets/Manual-Debuncher-Tunes.xls , or use the Java Manual Tune calculator on the Java W Index (http://www-bd.fnal.gov/appix/).

   a. If you are measuring the horizontal tune (ν_x), then the fraction portion of the horizontal tune is calculated from $\nu_x = 126 - \frac{f_s}{590018}$.
   b. If you are measuring the vertical tune (ν_y), then the fractional portion of the vertical tune is calculated from $\nu_y = \frac{f_s}{590018} - 126$.

11. Use the tune mults on P60 DEB10 subpages <9> and <10> to adjust the appropriate tune.
    a. Nominal horizontal tune as of February 2005 is 9.764 (In mid-2004 we were running at 9.77).
    b. Nominal vertical tune as of February 2005 is 9.785 (In mid-2004 we were running at 9.765).
12. Repeat steps 1 through 11 for the other plane (horizontal or vertical).
13. Optional: Further explore tune space by changing the tunes in both planes by small amounts and comparing P42 captures. The best value for the tune corresponds to the highest sideband peak.

14. Document any tuning changes in the Pbar electronic log book.

For a more detailed treatment of the Debuncher tunes procedure, please see the Full Procedure.

Printable Version:

The html version of this document is best for viewing, but not necessarily the best for printing. A printable version of this document is located in the Accelerator Division Documents Database Document 1452.
